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WHIRLED ANEMOMETERS.*

From "Nature."

In the course of the year 1872, Mr. R. H. Scott, F. R. S., suggested to the Meteorological Committee the desirability of carrying out a series of experiments on anemometers of different patterns. This suggestion was approved by the committee, and in the course of the same year a grant was obtained by Mr. Scott from the Government grant administered by the Royal Society for the purpose of defraying the espenses of the investigation. The experiments were not, however, carried out by Mr. Scott himself, but were intrusted to Mr. Samuel Jeffery, then Superintendent of the Kew Observatory, and Mr. G. M. Whipple, then First Assistant, the present Superintendent.

The results have never hitherto been published, and I was not aware of their nature till on making a suggestion that an anemometer of the Kew Standard pattern should be whirled in the open air, with a view of trying that mode of determining its proper factor, Mr. Scott informed me of what had already been done, and wrote to Mr. Whipple, requesting him to place in my hands the results of the most complete of the experiments, namely, those carried on at the Crystal Palace, which I accordingly obtained from him. The progress of the inquiry may be gathered from the following extract from Mr. Scott's report in return ing the unexpended balance of the grant:

"The comparisons of the instruments tested were first instituted in the garden of the Kew Observatory. This locality was found to afford an insufficient exposure.

"A piece of ground was then rented and enclosed within the Old Deer Park. The experiments here showed that there was a considerable difference in the indications of anemometers of different sizes, but it was not possible to obtain a sufficient range of velocities to furnish a satisfactory comparison of the instruments. Experiments were finally made with a rotating apparatus, a steam merry-go-round, at the Crystal Palace, which led to some results similar to those obtained by exposure in the Deer Park.

"The subject has however been taken up so much more thoroughly by Doctors Dohrandt and Thiesen (*vide* 'Repertorium für Meteorologie,' vols. iv. and v.), and by Dr. Robinson in Dublin, that it seems unlikely that the balance would ever be expended by me. I therefore return it with many thanks to the Government Grant Committee.

"The results obtained by me were hardly of sufficient value to be communicated to the Society."

On examining the records it seemed to me that they were well deserving of pub-

* "Discussion of the Results of some Experiments with Whirled Anemometers." Paper read at the Royal Society, by Prof. G. G. Stokes, Sec. R.S.

lication, more especially as no other experiments of the same kind have, so far as I know, been executed on an anemometer of the Kew standard pattern. In 1860 Mr. Glaisher made experiments with an anemometer whirled round in the open air at the end of a long horizontal pole,* but the anemometer was of the pattern employed at the Royal Observatory, with hemispheres of 3.75 inches diameter and arms of 6.725 inches, measured from the axis to the center of a cup, and so was considerably smaller than the Kew pattern. The experiments of Dr. Dohrandt and Dr. Robinson were made in a building, which has the advantage of sheltering the anemometer from wind, which is always more or less fitful, but the disadvantage of creating an eddying vorticose movement in the whole mass of air operated on; whereas in the ordinary employment of the anemometer the eddies it forms are carried away by the wind, and the same is the case to a very great extent when an anemometer is whirled in the open air in a gentle breeze. Thus, though Dr. Robinson employed among others an anemometer of the Kew pattern, his experiments and those of Mr. Jeffery are not duplicates of each other, even independently of the fact that the axis of the anemometer was vertical in Mr. Jeffery's and horizontal in Dr. Robinson's experiments; so that the greater completeness of the latter does not cause them to supersede the former.

In Mr. Jeffery's experiments the anemometers operated on were mounted a little beyond and above the outer edge of one of the steam merry-go-rounds in the grounds of the Crystal Palace, so as to be as far as practicable out of the way of any vortex which it might create. The distance of the axis of the anemometer from the axis of the "merry" being known, and the number of revolutions (n) of the latter during an experiment counted, the total space traversed by the anemometer was known. The number (N) of *apparent* revolutions of the anemometer, that is, the number of revolutions *relatively to the merry*, was recorded on a dial attached to the anemometer, which was read at the beginning and end of each experiment. As the machine would only go round one way the cups had to be taken off and replaced in a reverse position, in order to reverse the direction of revolution of the anemometer. The *true* number of revolutions of the anemometer was, of course, $N+n$, or $N-n$, according as the rotations of the anemometer and the machine were in the same or opposite directions.

The horizontal motion of the air over the whirling machine during any experiment was determined from observations of a dial anemometer with 3-inch cups on 8-inch arms, which was fixed on a wooden stand in the same horizontal plane as that in which the cups of the experimental instrument revolved, at a distance estimated at about 30 feet from the outside of the whirling frame. The motion of the centers of the cups was deduced from the readings of the dial of the fixed anemometer at the beginning and end of each experiment, the motion of the air being assumed as usual to be three times that of the cups.

The experiments were naturally made on fairly calm days, still the effect of the wind, though small, is not insensible. In default of further information, we must take its velocity as equal to the mean velocity during the experiment.

Let V be the velocity of the anemometer, W that of the wind, θ the angle between the direction of motion of the anemometer and that of the wind. Then the velocity of the anemometer relatively to the wind will be

$$\sqrt{V^2-2VW\cos\theta+W^2} \quad . \quad . \quad . \quad . \quad (a)$$

The mean effect of the wind in a revolution of the merry will be different according as we suppose the moment of inertia of the anemometer very small or very great.

If, as is practically the case, W be small as compared with V, the correction to be added to V on account of the wind may be shown to be $W\frac{2}{4}V$ on the first supposition, and $3W\frac{2}{4}V$ on the second.

Three anemometers were tried, namely, one of the old Kew standard pattern, one by Adie, and Kraft's portable anemometer. Their dimensions, &c., were as follows:

(*a*) *The Old Kew Standard.*—Diameter of arms between centers of cups 48 inches; diameter of cups 9 inches. Fixed

* "Greenwich Magnetical and Meteorological Observations," 1862, Introduction, p. li.

to machine at 22.3 feet from the axis of revolution.

(β) *Adie's Anemometer.*—Diameter of arms between centers of cups 13.4 inches; diameter of cups 2.5 inches. Fixed to machine at 20.7 feet from the axis of revolution.

(γ) *Kraft's Portable Anemometer.*—Diameter of arms between centers of cups 8.3 inches; diameter of cups 3.3 inches. Fixed to machine at 19.10 feet from the axis of revolution.

With each anemometer the experiments were made in three groups, with high, moderate, and low velocities respectively, averaging about 28 miles an hour for the high, 14 for the moderate, and 7 for the low. Each group again was divided into two subordinate groups, according as the cups were direct, in which case the directions of rotation of the merry and of the anemometer were opposite, or reversed, in which case the directions of the two rotations were the same.

The data furnished by each experiment were: the time occupied by the experiment, the number of revolutions of the merry, the number of *apparent* revolutions of the anemometer, given by the difference of readings of the dial at the beginning and end of the experiment, and the space S passed over by the wind, deduced from the difference of readings of the fixed anemometer at the beginning and end of the experiment.

The object of the experiment was of course to compare the mean velocity of the centers of the cups with the mean velocity of the air relatively to the anemometer. It would have saved some numerical calculation to have compared merely the spaces passed through during the experiment; but it seemed better to exhibit the velocities in miles per hour, so as to make the experiments more readily comparable with one another, and with those of other experimentalists. In the reductions I employed 4-figure logarithms, so that the last decimal in V in the tables cannot quite be trusted, but it is retained to match the correction for W, which it seemed desirable to exhibit to 0.01 mile.

On reducing the experiments with the low velocities I found the results extremely irregular. I was subsequently informed by Mr. Whipple that the machine could not be regulated at these low velocities, for which it was never intended, and that it sometimes went round fast, sometimes very slowly. He considered that the experiments in this group were of little, if any, value, and that they ought to be rejected. They were besides barely half as numerous as those of the moderate group. I have accordingly thought it best to omit them altogether.

In the complete paper tables are then given containing the reduced results of the individual experiments, and from them the mean results for the high and moderate velocities are collected in the following table, in which are also inserted the mean errors:

Anemometer.	Directions of rotation.	High velocities.				Moderate velocities.					
		Mom. inert. small.		Mom. inert. large.		Mom. inert. small.		Mom. inert. large.			
		p. c.	m. e.	p. c.	m. e.	p. c.	m. e.	p. c.	m. e.		
Kew.	Opposite..	122.6	2.4	121.9	2.3	115.1	4.9	113.2	5.2		
	Alike.....	118.4	2.9	117.5	2.8	109.7	4.5	108.5	5.1		
	Mean...	120.5	—	119.7	—	112.4	—	110.8			
Adie.	Opposite..	95.1	2.3	94.2	2.3	88.5	4.5	86.8	5.0		
	Alike.....	98.0	6.5	97.3	6.5	82.6	7.3	81.0	7.3		
	Mean...	96.5	—	95.7	—	85.5	—	83.9			
Kraft.	Opposite..	101.5	2.6	100.8	2.5	89.1	4.8	89.9	5.1		
	Alike.....	100.8	1.2	99.4	1.3	87.8	5.0	88.0	6.0		
	Mean..	101.1	—	100.1	—	88.4	—	88.4			

The mean errors exhibited in the above table show no great difference according, as we suppose, the moment of inertia of the anemometer small or large in correcting for the wind. From the mean errors we may calculate nearly enough, by the usual formulæ, the probable errors of the various mean percentages for rotations opposite and alike. The probable errors of these mean percentages come out as follows:

	For high velocities.		For moderate velocities.
Kew.....	1.0	..	2.7
Adie.....	1.5	..	2.0
Kraft.....	0.9	..	1.8

These probable errors are so small that it appears that for the high and even for the moderate velocities the experiments are extremely trustworthy, except in so far as they may be affected by *systematic* sources of error.

It may be noticed that the difference of the percentages, according as the directions of rotation of the anemometer and of the merry are opposite or alike, is greatest for the Kew, in which the ratio of r to R is greatest, r denoting the radius of the arm of the anemometer, and R the distance of its axis from the axis of revolution of the machine, and appears to be least (when allowance is made for the two anomalous experiments in the group "Adie H+") for the Kraft, for which r/R is least. In the Kraft indeed the differences are roughly equal to the probable errors of the means. In these whirling experiments r/R is always taken small, and we might expect the correction to be made on account of the finiteness of R to be expressible in a rapidly converging series according to powers of r/R, say

$$A'\frac{r}{R}+B'\left(\frac{r}{R}\right)^2+C'\left(\frac{r}{R}\right)^3+\ldots$$

We may in imagination pass from the case of rotations opposite to that of rotations alike, by supposing R taken larger and larger in successive experiments, altering the angular velocity of revolution so as to preserve the same linear velocity for the anemometer, and supposing the increase continued until R changes sign in passing through infinity, and is ultimately reduced in magnitude to what it was at first. The ideal case of $R=\infty$ is what we aim at, in order to represent the motion of a fixed anemometer acted on by perfectly uniform wind by that of an anemometer uniformly impelled in a rectilinear direction in perfectly still air. We may judge of the magnitude of the leading term in the above correction, provided it be of an odd order, by that of the difference of the results for the two directions of rotation. Unless therefore we had reason to believe that A′ were o, or at least very small compared with B′, we should infer that the whole correction for the finiteness of R is very small, and that it is practically eliminated by taking the mean of the results for rotations opposite and rotations alike.

We may accept, therefore, the mean results as not only pretty well freed from casual irregularities which would disappear in the mean of an infinite number of experiments, but, also, most probably, from the imperfection of the representation of a rectilinear motion of the anemometer by motion in a circle of the magnitude actually employed in the experiments.

Before discussing further the conclusions to be drawn from the results obtained, it will be well to consider the possible influence of systematic sources of error.

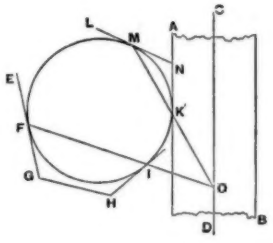
1. *Friction.*—No measure was taken of the amount of friction, nor were any special appliances used to reduce it; the anemometers were mounted in the merry just as they are used in actual registration. Friction arising from the weight is guarded against as far as may be in the ordinary mounting, and what remains of it would act alike in the ordinary use of the instrument and in the experiments, and as far as this goes, therefore, the experiments would faithfully represent the instrument as it is in actual use. But the bearings of an anemometer have also to sustain the lateral pressure of the wind, which in a high wind is very considerable; and the construction of the bearing has to be attended to in order that this may not produce too much friction. So far the whirled instrument is in the same condition as the fixed. But besides the friction arising from the pressure of the artificial wind, a pressure which acts in a direction tangential to the circular path of the whirled anemometer, there is the pressure arising from the centrifugal force. The highest velocity in the experiments was about thirty miles an hour, and at this rate the centrifugal force would be about three times the weight of the anemometer. This pressure would considerably exceed the former, at right angles to which it acts, and the two would compound into one equal to the square root of the sum of their squares. The resulting friction would exceed a good deal that arising from the

pressure of the wind in a fixed anemometer with the same velocity of wind, natural or artificial, and would sensibly reduce the velocity registered, and accordingly raise the coefficient which Dr. Robinson denotes by m, the ratio, namely, of the velocity of the wind to the velocity of the centers of the cups. It may be noticed that the percentages collected in the above table are very distinctly lower for the moderate velocities than for the high velocities. Such an effect would be produced by friction; but how far the result would be modified if the extra friction due to the centrifugal force were got rid of, and the whirled anemometer thus assimilated to a fixed anemometer, I have not the means of judging, nor again how far the percentages would be still further raised if friction were got rid of altogether.

Perhaps the best way of diminishing friction in the support of an anemometer is that devised and employed by Dr. Robinson, in which the anemometer is supported near the top on a set of spheres of gun-metal contained in a box with a horizontal bottom and vertical side which supports and confines them. For vertical support this seems to leave nothing to be desired, but when a strong lateral pressure has to be supported as well as the weight of the instrument, it seems to me that a slight modification of the mode of support of the balls might be adopted with advantage. When a ball presses on the bottom and vertical side of its box, and is at the same time pressed down by the horizontal disc attached to the shaft of the anemometer which rests on the balls, it revolves so that the instantaneous axis is the line joining the points of contact with the fixed box. But if the lateral force of the wind presses the shaft against the ball, the ball cannot simply roll as the anemometer turns round, but there is a slight amount of rubbing.

This, however, may be obviated by giving the surfaces where the ball is in contact other than vertical or horizontal direction.

Let AB be a portion of the cylindrical shaft of an anemometer; CD the axis of the shaft; EFGHI a section of the fixed box or cup containing the balls; LMN a section of a conical surface fixed to the shaft by which the anemometer rests on its balls; FIKM a section of one of the balls; F, I, the points of contact of the ball with the box; M the point of contact with the supporting cone; K the point of contact, or all but contact, of



the ball with the shaft. The ball is supposed to be of such size that when the anemometer simply rests on the balls by its own weight, being turned perhaps by a gentle wind, there are contacts at the points M, F, I, while at K the ball and shaft are separated by a space which may be deemed infinitesimal. Lateral pressure from a stronger wind will now bring the shaft into contact with the ball at the point K also, so that the box on the one hand and the shaft with its appendage on the other will bear on the ball at four points. The surface of the box, as well as that on the cone LN, being supposed to be one of revolution round CD, those four points will be situated in a plane through CD, which will pass of course through the center of the ball.

If the ball rolls without rubbing at any one of the four points F, I, K, M as the anemometer turns round, its instantaneous axis must be the line joining the points of contact F, I, with the fixed box. But as at M and K likewise there is nothing but rolling, the instantaneous motion of the ball may be thought of as one in which it moves as if it were rigidly connected with the shaft and its appendage, combined with a rotation over LNAB, supposed fixed. For the two latter motions the instantaneous axes are CD, MK respectively. Let MK produced cut CD in O. Then since the instantaneous motion is compounded of rotations round two axes passing through O, the instantaneous axis must pass through O. But this axis is FI. Therefore FI must pass through O. Hence the two lines FI, MK must intersect the axis of the

shaft in the same point, which is the condition to be satisfied in order that the ball may roll without rubbing, even though impelled laterally by a force sufficient to cause the side of the shaft to bear on it. The size of the balls and the inclinations of the surfaces admit of considerable latitude subject to the above condition. The arrangement might suitably be chosen something like that in the figure. It seems to me that a ring of balls constructed on the above principle would form a very effective upper support for an anemometer whirled with its axis vertical. Possibly the balls might get crowded together on the outer side by the effect of centrifugal force. This objection, should it be practically found to be an objection, would not of course apply to the proposed system of mounting in the case of a fixed anemometer. Below, the shaft would only require to be protected from lateral motion, which could be done either by friction wheels or by a ring of balls constructed in the usual manner, as there would be only three points of contact.

2. *Influence on the Anemometer of its own Wake.*—By this I do not mean the influence which one cup experiences from the wake of its predecessor, for this occurs in the whirling in almost exactly the same way as in the normal use of the instrument, but the motion of the air which remains at any point of the course of the anemometer, in consequence of the disturbance of the air by the anemometer, when it was in that neighborhood in the next preceding and the still earlier revotions of the whirling instrument.

It seems to me that in the open air, where the air impelled by the cups is free to move into the expanse of the atmosphere, instead of being confined by the walls of a building, this must be but small, more especially as the wake would tend to be carried away by what little wind there might be at the time. On making some inquiries from Mr. Whipple as to a possible vorticose movement created in the air through which the anemometer passed, he wrote as follows: "I feel confident that under the circumstances the tangential motion of the air at the level of the cups was so small as not to need consideration in the discussion of the results. As in one or two points of its revolution the anemometer passed close by some small trees in full leaf, we should have observed any eddies or artificial wind had it existed, but I am sure we did not."

3. *Influence of the Variation of the Wind; first, as regards Variations which are not Rapid.*—During the twenty or thirty minutes that an experiment lasted there would of course be numerous fluctuations in the velocity of the wind, the mean result of which is alone recorded. The period of the changes (by which expression it is not intended to assert that they were in any sense regularly periodic) might be a good deal greater than that of the merry, or might be comparatively short. In the high velocities, at any rate, in which one revolution took only three or four seconds, the supposition that the period of the changes was large compared with one revolution is probably a good deal nearer the truth than the supposition that it is small.

On the former supposition the correction for the wind during two or three revolutions of the merry would be given by the formulæ already employed, taking for W its value at the time. Consequently the total correction will be given by the formulæ already used if we substitute the mean of W^2 for the square of mean W. The former is necessarily greater than the latter, but how much we cannot tell without knowing the actual variations. We should probably make an outside estimate of the effect of the variations if we supposed the velocity of the wind twice the mean velocity during half the duration of the experiment, and nothing at all during the remainder. On this supposition the mean of W^2 would be twice the square of mean W, and the correction for the wind would be doubled. At the high velocities of revolution, the whole correction for the wind is so very small that the uncertainty arising from variation as above explained is of little importance, and even for the moderate velocities it is not serious.

4. *Influence of Rapid Variations of the Wind.*—Variations of which the period is a good deal less than that of the revolutions of the whirling instrument act in a very different manner. The smallness of the corrections for the wind hitherto employed depends on the circumstance

that with uniform wind, or even with variable wind, when the period of variation is a good deal greater than that of revolution of the merry, the terms depending on the first power of W, which letter is here used to denote the momentary velocity of the wind, disappear in the mean of a revolution. This is not the case when a particular velocity of wind belongs only to a particular part of the circle described by the anemometer in one revolution. In this case there will in general be an outstanding effect depending on the first power of W, which will be considerably larger than that depending on W^2. Thus suppose the velocity of whirling to be thirty miles an hour, and the average velocity of the wind three miles an hour, the correction for the wind supposed uniform, or if variable, then with not very rapid variations, will be comparable with 1 per cent. of the whole; whereas, with rapid variations, the effect in any one revolution may be comparable with 10 per cent. There is, however, this important difference between the two: that whereas the correction depending on the square leaves a positive residue, however many experiments be made, the correction depending on the first power tends ultimately to disappear, unless there be some cause tending to make the average velocity of the wind different for one azimuth of the whirling instrument from what it is for another. This leads to the consideration of the following conceivable source of error.

5. *Influence of Partial Shelter of the Whirling Instrument.*—On visiting the merry-go-round at the Crystal Palace, I found it mostly surrounded by trees coming pretty near it, but in one direction it was approached by a broad open walk. The consequence is that the anemometer may have been unequally sheltered in different parts of its circular course, and the circumstances of partial shelter may have varied according to the direction of the wind. This would be liable to leave an uncompensated effect depending on the first power of W. I do not think it probable that any large error was thus introduced, but it seemed necessary to point out that an error of the kind may have existed.

The effect in question would be eliminated in the long run if the whirling instrument were capable of reversion, and the experiments were made alternately with the revolution in one direction, and the reverse. For then, at any particular point of the course at which the anemometer was more exposed to wind than on the average, the wind would tend to increase the velocity of rotation of the anemometer for one direction of revolution of the whirling instrument just as much, ultimately, as to diminish it for the other. Mere reversion of the cups has no tendency to eliminate the error arising from unequal exposure in different parts of the course. And even when the whirling instrument is capable of reversion it is only very slowly that the error, arising from partial shelter, is eliminated compared with that of irregularities in the wind; of those irregularities, that is to say, which depend on the first power of W. For these irregularities go through their changes a very great number of times in the course of an experiment lasting perhaps half an hour, whereas the effect of partial shelter acts the same way all through one experiment. It is very desirable therefore that in any whirling experiments carried on in the open air, the condition of the whirling instrument as to exposure or shelter should be the same all round.

The trees, though taller than the merry when I visited the place last year, were but young, and must have been a good deal lower at the time that the experiments were made. Mr. Whipple does not think that any serious error is to be apprehended from exposure of the anemometer during one part of its course and shelter during another.

From a discussion of the foregoing experiments it seems to me that the following conclusions may be drawn:

1. That, at least for high winds, the method of obtaining the factor for an anemometer, which consists in whirling the instrument in the open air, is capable, with proper precautions, of yielding very good results.

2. That the factor varies materially with the pattern of the anemometer. Among those tried, the anemometers with the larger cups registered the most wind, or in other words required the lowest factors to give a correct result.

3. That with the large Kew pattern,

which is the one adopted by the Meteorological Office, the register gives about 120 per cent. of the truth, requiring a factor of about 2.5, instead of 3. Even 2.5 is probably a little too high, as friction would be introduced by the centrifugal force, beyond what occurs in the normal use of the instrument.

4. That the factor is probably higher for moderate than for high velocities; but whether this is solely due to friction the experiments do not allow us to decide.

Qualitatively considered, these results agree well with those of other experimentalists. As the factor depends so much on the pattern of the anemometer it is not easy to find other results with which to compare the actual numbers obtained, except in the case of the Kew standard. The results obtained by Dr. Robinson, by rotating an anemometer of this pattern without friction purposely applied are given at pp. 797 and 799 of the *Phil. Trans.* for 1878. The mean of a few taken with velocities of about 27 miles an hour in still air gave a factor 2.36, instead of 2.50 as got from Mr. Jeffery's experiments. As special anti friction appliances were used by Dr. Robinson, the friction in Mr. Jeffery's experiments was probably a little higher. If such were the case the factor ought to come out a little higher than in Dr. Robinson's experiments, which is just what it does. As the circumstances of the experiments were widely different with respect to the vorticose motion of the air produced by the action of the anemometer in it, we may, I think, conclude that no very serious error is to be apprehended on this account.

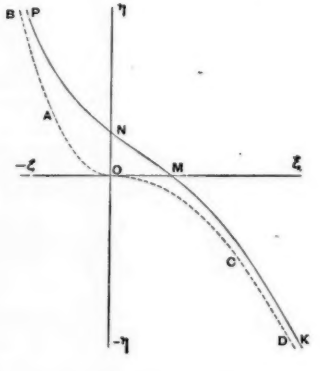
In a later paper (*Phil. Trans.* for 1880, p. 1055), Dr. Robinson has determined the factor for an anemometer (among others) of the Kew pattern by a totally different method, and has obtained values considerably larger than those given by the former method. Thus the limiting value of the factor m corresponding to very high velocities, is given at p. 1063 as 2.826, whereas the limiting value obtained by the former method was only 2.286. Dr. Robinson has expressed a preference for the later results. I confess I have always been disposed to place greater reliance on the results of the Dublin experiments, which were carried out by a far more direct method, in which I cannot see any flaw likely to account for so great a difference. It would be interesting to try the second method in a more favorable locality.

I take this opportunity of putting out some considerations respecting the general formula of the anemometer, which may perhaps not be devoid of interest.

The problem of the anemometer may be stated to be as follows: Let a uniform wind with velocity V act on a cup anemometer of given pattern, causing the cups to revolve with a velocity v, referred to the center of the cups, the motion of the cups being retarded by a force of friction F; it is required to determine v as a function of V and F, F having any value from O, corresponding to the ideal case of a frictionless anemometer, to some limit F_1, which is just sufficient to keep the cups from turning. I will refer to my appendix to the former of Dr. Robinson's papers (*Phil. Trans.* for 1878, p. 818), for the reasons for concluding that F is equal to V^2, multiplied by a function of V/v. Let

$$V/v=\xi, \qquad F/V^2=\eta,$$

then if we regard ξ and η as rectangular co-ordinates we have to determine the form of the curve, lying within the positive quadrant $\xi o \eta$, which is defined by those co-ordinates.



We may regard the problem as included in the more general problem of determining v as a function of V and F, where V is positive, but F may be of any

magnitude and sign, and therefore v also.* Negative values of F mean, of course, that the cups, instead of being retarded by friction, are acted on by an impelling force making them go faster than in a frictionless anemometer, and values greater than F_1 imply a force sufficient to send them round with the concave sides foremost.

Suppose now F to be so large, positive or negative, as to make v so great that V may be neglected in comparison with it, then we may think of the cups as whirled round in quiescent air in the positive or usual direction when F is negative, in the negative direction when F is greater than F_1. When F is sufficiently large the resistance may be taken to vary as v^2. For equal velocities v it is much greater when the concave side goes foremost than when the rotation is the other way. For air impinging perpendicularly on a hemispherical cup Dr. Robinson found that the resistance was as nearly as possible four times as great when the concave side was directed to the wind as when the convex side was turned in that direction (*Transactions* of the Royal Irish Academy, vol. xxii. p. 163). When the air is at rest and the cups are whirled round, some little difference may be made by the wake of each cup affecting the one that follows. Still we cannot be very far wrong by supposing the same proportion, 4 to 1, to hold good in this case. When F is large enough and negative, F may be taken to vary as v^2, say, to be equal to $-Lv^2$. Similarly, when F is large enough and positive, F may be taken equal to $L'v^2$, where in accordance with the experiment referred to, L′ must be about equal to 4 L. Hence we must have nearly

$\eta = -L\xi^2$, when ξ is positive and very large;

$\eta = 4L\xi^2$, when ξ is negative and very large.

Hence, if we draw the semi-parabola O A B corresponding to the equation $\eta = 4L\xi^2$ in the quadrant $\eta O - \xi$, and the semi-parabola O C D with a latus lectum four times as great in the quadrant $\xi O - \eta$, our curve at a great distance from the origin must nearly follow the parabola O A B in the quadrant $\eta O - \xi$, and the parabola O C D in the quadrant $\xi O - \eta$, and between the two it will have some flowing form such as P N M K. There must be a point of inflection somewhere between P and K, not improbably within the positive quadrant $\xi O - \eta$. In the neighborhood of this point the curve N M would hardly differ from a straight line. Perhaps this may be the reason why Dr. Robinson's experiments in the paper published in the *Phil. Trans.* for 1878 were so nearly represented by a straight line.

*Of course v must be supposed not to be so large as to be comparable with the velocity of sound, since then the resistance to a body impelled through air, or having air impinging on it, no longer varies as the square of the velocity.

NOTE ON THE FRICTION OF TIMBER PILES IN CLAY.

By ARTHUR CAMERON HERTZIG, Assoc. M. Inst. C.E.

From Selected Papers of the Institution of Civil Engineers.

The frictional resistance to motion of piles in different soils is not easily ascertained or well known. The difficulty arises from the fact that when piles are once driven in the foundations of bridges, &c., no occasion, as a rule, occurs by which their adhesion can be afterwards determined. In isolated cases, where foundations have failed, an approximate connection has been formed between the superincumbent weight and the frictional resistance of the piles; these cases, though not numerous, afford some information on the subject. Direct experiments are also but few, so that the data from which to obtain a correct knowledge are not ample. As a small contribution the author submits the present short note of several observations.

The removal of a cofferdam of whole-timber piles at Hull gave the opportunity for taking the observations.

Previous to the extension of the Albert dock westward a circular cofferdam was driven at the west end of the dock, to keep out the water from the new works. This dam consisted of two rows of whole-

timber piles, 5 feet apart, the radius of the outer row being 205 feet. The intervening space was filled with puddled clay to above high-water mark. The dam was made in 1874, and the piles, after remaining in the ground five years, were drawn in January and February, 1880.

The clay was reached at a depth of 28 feet below the level of the quay. This was a compact bluish clay, and above it there were from 3 to 5 feet of peat, above which again were silt and sand. The west end of the Albert dock was finished with a pitched slope at an inclination of 3 to 1, and the dam was driven into this slope, the points of the piles entering the ground at about the level of the peat, or slightly above. Thus the piles may be considered as having been chiefly in the stiff blue clay. Before the piles were drawn the clay puddle between the two rows was removed to as low a point as possible, which was about 13 feet below the level of the quay, or rather under high-water mark of ordinary neap tides. The clay puddle that could not be removed would increase to a small extent the frictional resistance to drawing. The clay having been got out the piles were drawn, commencing at the north end of the dam.

A "cat head" was used to draw the piles. This consisted of a framework of whole timbers, to the cross head of which was fixed the tackle for lifting—a pair of blocks and six-part chain. The free end of the chain was led round the barrel of a winch, capable of being worked by single or double purchase. The whole of the apparatus stood upon a platform upon the heads of the piles, and was shifted southward as the piles northward were drawn. To the lower pulley block a heavy sling chain was attached, and this was slung round the pile to be drawn and secured with wedges.

The power exerted by one, two or more men working at the apparatus was previously ascertained by allowing them to lift certain known dead weights with the winch and tackle, under exactly the same conditions as those under which they were used in drawing the piles of the dam. The radius of the handle of the winch was 18 inches, and it was found that the extreme power which a man could put into the machine throughout the revolution was 27 lbs. effective. That is to say, the extreme weight that could be raised by one man, together with the friction of the apparatus, was represented by 27 lbs. at the handle. The same men employed in drawing the dam worked the winch to ascertain the weights lifted; these were as follows:

Number of men.	Single purchase.			Double purchase.	
	Tons.	cwt.		Tons.	cwt.
1.....	2	10	..	9	10
2.....	4	0	..	15	0
3.....	6	0	..	22	10
4.....	7	10	..	28	0
5.....	9	10	..	35	10
6.....	11	0	..	41	0

The winch was generally used in double purchase, and in commencing to draw a pile perhaps three men were first put at the handle. If they could not move the pile four were tried, and if these could not do it then five, and so on. Suppose, for instance, five men were able to draw the pile, while four could not; the ganger in charge would enter in his book, kept for the purpose, whether the pile which would not move with four men at the handle, moved easily or otherwise when five were tried. Three degrees were used to designate the difficulty in drawing, viz., "easy," "hard," and "very hard," and against each pile in the book was entered the corresponding degree of difficulty experienced in drawing it. Thus, knowing the extreme loads that four and five men could lift, it was possible to estimate approximately the actual pull required to draw the pile. It would have been easy with a dynamometer to have had the exact pull registered in every case; but such an instrument was not available, and the author had to be contented with the approximate estimate. The results, though not pretending to great accuracy, are perhaps as useful as if they did; for in any case where the knowledge of the friction in earth is required, it is sufficient to be able to estimate to within a few tons.

In addition to the observation on the pull required to draw the pile, the length and scantling of each pile were taken, and also the depth to which it had been driven in the ground. These were all the observations required.

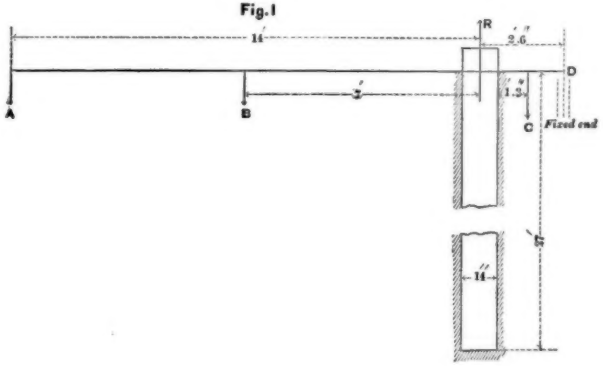
Four hundred and twenty piles were drawn, upon which three hundred observ-

ations were taken. The length varied between 20 feet and 49 feet, a few of the short piles being used in the south end of the dam, where it met the pitched slope of the side of the dock. The average length of all was 40 feet. The average scantling was $12\frac{1}{2}$ inches square=156 square inches, the sizes varying between 12 inches by 10 inches=120 square inches, and 15 inches by 14 inches=210 square inches. The depths to which the piles were driven in the ground ranged between 6 feet and 30 feet, the average being $18\frac{1}{4}$ feet. The average superficial area of pile below the ground line was 76 feet.

As the piles were not tongued and grooved, but simply driven close together, and as they were drawn consecutively, only two sides of each pile would have to be taken in estimating the area to which the friction in the soil was due. The average area below ground being 76 square feet, half of this, or 38 square feet, will be subject to friction. The gross resistance, as measured by the pull required to draw three hundred piles, was 33.87 tons per pile. From this must be deducted two items, the weight of the pile and the power required to overcome the suction. For the piles of average scantling, $12\frac{1}{2}$ inches square, there will be required a maximum pull of 156 × 15 lbs.=2,340 lbs. to overcome the resistance of suction, taking the worst condition, viz., that of a perfect vacuum. The weight of the pile containing 44 cubic feet may be taken at 1 ton. Thus, making allowance for these items, the net frictional resistance of the soil will be 31.82 tons per pile; and this, on an area of 38 superficial feet, gives 1,875 lbs. as the co-efficient of friction per square foot in contact with the soil. The piles were of ordinary rough Memel balk timber. With sawn timber there would probably be a slight reduction in the friction.

In other soils, and with a surface other than timber, the co-efficient would be different. During the progress of a 14-inch boring for water the author observed what force was required to press down the tube lining the hole. This lining was of iron tubing, 14 inches in diameter, and $\frac{1}{16}$ inch thick. The bottom of the tube had reached a depth of 24 feet, and the boring tool was working at

Fig. 1



a depth of 28 feet, having passed through 20 feet of made ground and 8 feet of silty clay. The hole having been cleared out, the tube was forced down as follows:

A=weight of two men=3 cwt.
B=weight of 14 feet, length of four planks $12\frac{1}{2}$ inches by 3 inches=7 cwt.
C=weight of 2 feet 6 inches length of same planks=$1\frac{1}{4}$ cwt.
R=the resistance opposed by the tube.

The end D of the planks being anchored down, it follows from the above that R=47 cwt. The depth being 27 feet, and the diameter 14 inches, the superficial area in contact with the earth=100 square feet; so that the skin friction of the tube in this light earth amounted to 0.47 cwt. per square foot=53 lbs.

Several examples of the friction of soils

on piles and piers are recorded in the Minutes of Proceedings.

In close connection with this subject is the relation between the energy imparted to a pile in driving and the weight it will afterwards carry, or the force required to draw it, if it be assumed that friction only is the resistance to motion in each case. The author has deduced a simple formula for ascertaining the extreme load that could be carried by a pile after a definite amount of driving.

If P = the extreme resistance of the pile in tons,
x = the energy of the last blow, in foot-tons = the product of the weight of the monkey into the height of fall,
y = the "set" of the pile at the last blow, in feet, then the formula is:

$$y = \frac{x}{P} - \frac{P}{500}.$$

The piles in the dam were driven with a 1-ton monkey falling 5 to 6 feet, and the set of the pile under the last blow varied between $\frac{1}{2}$ and $\frac{3}{4}$ inch.

Applying these quantities to the preceding formula, the extreme resistance is from 35 to 45 tons, while the average resistance to the drawing of the piles was actually something under 34 tons—a result which shows that the formula is tolerably correct for the extreme supporting power of a pile in its worst condition, that of resistance by lateral friction only.

THE PROTECTIVE WORKS FOR PREVENTING THE THREATENED OUTBREAK OF THE SOUTH RANGITATA RIVER, N. Z.

By JOHN HENRY LOWE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

Since the construction of railways in the Middle Island of New Zealand, the sudden and violent floods to which the country is liable have occasioned much trouble and expense. The rivers which traverse the Canterbury plains are amongst the most formidable when in flood.

These plains form the central portion of the eastern slope of the Middle Island. They extend for a length of about 100 miles, by a breadth of 40 miles, from the sea to the foot of the mountain ranges, and are composed almost entirely of shingle of great depth, overlaid with a light sandy soil, principally covered with tussock grass. The plains, although presenting to the eye the appearance of an unbroken level, have a fall towards the sea varying from 18 feet to 40 feet to the mile.

Three principal rivers—the Waimakariri, the Rakaia and the Rangitata—traverse these plains, and are mainly fed by the melting snows of the Southern Alps, augmented by the copious rains that fall over their extensive basins. Numerous minor streams and watercourses also intersect the plains, rising among the lower hills at the foot of the main ranges. The Waimakariri, the most northerly of these rivers, flows about 14 miles northward of Christchurch. It is the only one that has yet extended its bed beyond the limits of the gravels. The others are still discharging gravels into the sea. No doubt the plains have been formed by the accumulated deposits of shingle brought down, through a long course of time, by the frequently recurring floods in these rivers. In the neighborhood of the hills the rivers have cut deep channels through the gravel beds, showing in places an abrupt face of shingle 400 feet in height. These shingly bluffs decrease in height down the river, and in 10 miles have dwindled to about 30 feet; at the same time the river bed widens into a bare waste of shingle, over which the water flows in innumerable irregular, ever-shifting streams, sometimes dividing in wide and shallow reaches, again converging in narrow channels in which the river flows swift and deep. The abrupt terrace face now separates into minor ter-

races rising one above another, receding farther and farther from the watercourse. About 10 miles from the sea the banks almost disappear, the bed is choked with gravel, and is in many places raised to a higher level than the adjacent country.

The main line of railway along the east coast of the Middle Island traverses these plains. It crosses the Waimakariri on the tideway below the traveling gravels; a wide belt of drifting sand borders the river on each side, which is overflowed by every flood. On this margin the railway works used frequently to be washed away, but they are now rendered more secure.

The Rakaia is crossed by a piled timber bridge 1 mile in length, which has suffered many severe strains from the floods. Its approaches were often carried away until sufficiently raised and protected with rockwork groynes.

The Rangitata is the southernmost of the rivers that cross the Canterbury plains. After leaving the hills the northern side of the river is confined by high terraces for the greater part of its course to the sea. The southern banks are, however, low and broken, and the country to the southward falls rapidly away from the river. About 8 miles from the foot of the hills the river parts into two distinct groups of channels, known as the north and south branches, uniting again near the sea, and so forming the Rangitata Island.

The railway crosses the two channels of the river about 4 miles below the main parting. There are two railway bridges about 1 mile apart, each bridge having thirty two spans of 60 feet, with pile-work piers. The main volume of water in the floods frequently changes from one branch to the other, being guided at the parting by the shifting beds of shingle that the river is continually moving forward.

The overflowing of the south branch during heavy floods in 1878 occasioned serious apprehensions for the railway works. At a point about 2 miles above the railway bridge a large overflow took place, which was extended and deepened by every successive freshet; the overflowing water concentrated in an old course and made a straight run for the sea, carrying away fences, railway banks, crops, and much valuable land.

It soon became evident that a few more floods would deepen this overflow, and allow the whole river to take a new course to the sea, so entailing the construction of another costly railway bridge, besides doing enormous damage to the country. Recognizing the necessity of checking the outbreak of the river, the Government approved plans submitted for the purpose, and authorized the estimated expenditure.

In designing these works the principal difficulties to be contended with were first, the absence of a base of operations (all the natural banks being so low, and the soil so friable as to be easily washed down by the flood water), and also the lack of any ordinary material for building. No rough stone was procurable nearer than 80 miles by rail, and 4 miles of cartage, which would have made it very costly. It was ultimately decided to make use of the material on the spot, viz., the boulders of the river bed. The regular diminution in size of the boulders and shingle down stream, so often remarked upon, is very observable in this river, and, owing probably to the considerable fall, the change is great within comparatively short distances.

About 8 miles above the railway the river bed is covered with boulders of from 2 to 3 cubic feet in size; at the breach, 4 miles lower down, the bed is chiefly composed of coarse shingle, but interspersed with numerous large boulders, 2 cubic feet being about the largest; another 4 miles lower down, viz., at the railway bridge, few boulders can be found more than $\frac{1}{2}$ cubic foot in size. The appearance presented by shingly river beds after floods, giving the idea of rough hand-set pitching, is also very marked in this river bed. While the flood is running at full force the boulders, shingle, sand and silt are being carried forward at rates varying with the strength of the current and the weight of the different bodies propelled. They tumble along without any apparent order while the flood is at its height, but as the flood subsides and the propelling force of the current diminishes, the heavier stones begin to settle first, the smaller ones are carried lower down, and thus the process of sorting into sizes is accomplished. Again, as each stone in turn has nearly reached the limit of carriage by the water,

the process of "pitching" is carried on. Every stone which has one side flatter than its other surfaces tumbles along at random, until its flattest side happens to take a position inclined against the current, the dip having a particular angle of inclination with the horizon, and the strike parallel with the current, the angle being about 30°. As long as the flat side takes any other position the water has considerably more power to move the stone, either by lifting, turning or rolling it, than it has when it lies in the position described, for the force of the current is then deflected upward without having any tendency to move the stone, but rather tends to press it down and keep it steady; and thus each stone in turn becomes arrested in that particular position. This indicates the form and position of an obstruction to a running stream best calculated to withstand its force. It also follows from the tendency of the river to sort its stones into sizes, that if boulders are piled in any given part of a river bed, of an average weight exceeding the weight of the stones that the river has left there in its ordinary course, it will be beyond the power of the river to move the stones so placed.

The erection of earth embankments to confine the overflow of the South Rangitata was tried some years ago, but the river scoured its natural banks, and the ground on which the artificial embankments were built was carried away from under them.

To obtain more permanent results the work has to be placed in the river bed itself. Shingle-carrying rivers invariably run in successive shallows and falls. In one place the water concentrates into a comparatively narrow, deep torrent, with great fall, where it cuts away the bottom on one side; then again it widens out, slackens speed, and deposits the material excavated above in a wide and shallow beach. In such places it frequently parts into different channels, which may again unite lower down.

To ensure economy in protective works in these rivers it is requisite that the least possible area of the artificial embankments should be exposed to the current. The plan adopted was to form groynes having strong ends projecting into the current of the river, with connecting banks, inexpensively formed, to stand in still water under the protection of the groynes.

The scour and outbreak of the river which are sought to be prevented generally take place at the channels where the river is cutting the bank, and at that point it is most disadvantageous to attempt to cope with it. The stream to be checked or diverted must be traced up to the next shoal or parting above. At this point the velocity of the river is less, the depth of water is less, the possible rise of flood is less, the outfall of the water to be artificially intercepted will be the best, and therefore the tendency of the groyne to raise the superincumbent flood water will have the least effect. So far the shallowest part of the fall, where the stream separates and runs slowest, would be indicated as the best position for the groyne. But, on the other hand, if placed at that point the work would, when finished, stand in the full current of the flood and be exposed to scour along its foot.

The choice, then, lies on a line just below the top of the fall. A bank constructed across the funnel of the intercepted stream, just below the fall, will stand in still water not exposed to scour, while the water cut off from that channel will have a ready outfall down the neighboring channel. The embankment only requires sufficient height to overtop the highest flood to be perfectly safe. The space between the bank and the river current is soon filled up with gravel and sand, and the interstices between the stones in the work become completely grouted with silt. The bank having been made across the channel of the intercepted stream is turned up river on the shallow ground of the parting, and there the groyne is built which has to withstand all the force of the current of the river.

In building the groynes a pit was excavated in the river bed about 40 feet square and 20 feet deep. In this pit iron bark logs were placed at an angle of about 30°, the lower ends spread out like a fan, the upper ends being gathered together and bolted to a horizontal bar, like a ridge pole, at the level of the top of the embankment. A stout waling was then bolted along the feet of all the rakers, and a layer of the largest bould-

ers filled over the whole area, inside the timbers, up to the level of the waling; next a layer of stout manuka poles and fascines was laid at right angles to the walings, with ends projecting over the bottom waling; then another waling was bolted to the rakers holding down the ends of the poles and fascines, and another course of boulders followed, and so on up to the top. The whole of the pit outside the groyne was lastly filled up with the largest boulders procurable to the level of the original surface of the bed.

In order to divert all the flood water from the breach in the bank of the South Rangitata river, four separate channels had to be treated as above; the stop banks extended about ½ mile in length, with seven main protecting groynes and several minor ones, which were inserted to gather silt along the banks and keep off the current. The structure was begun at the lower end and continued up stream, as by so doing all intercepted water is finally disposed of. Works undertaken by commencing at the upper end often fail, because the water diverted above is accumulated in the last channel, and has all to be combated together at the last.

Progress was retarded by several severe floods, which carried away embankments before they or their groynes were finished. These were, however, rendered more substantial in consequence. A bank was completed about 14 feet in height, in a depth of about 8 feet of water. The protecting groyne was not finished when a flood came on. It washed away the upper 7 feet of the bank, and filled up the channel with large stones and boulders to the level of the lower 7 feet of the bank. For every yard in depth so washed off the bank, about 200 cubic yards of material were deposited in the channel. Had the bank stood, the upper side would have been occupied by degrees with light silt and sand, where now it is filled with heavy material.

The cost of the works was about £4,000; they were executed in eleven months, ending in August, 1879, by twenty-two men and eight horses. Each groyne cost on an average £200. The embankments contained 20,000 cubic yards of boulders, and have since stood several severe floods without damage.

The banks are capable of withstanding floods nearly up to their full height, and the groynes can be covered by floods without injury. The river bed has become somewhat piled up round all the groynes, and the pockets above are rapidly filling with silt. The main current of the river now runs on the opposite side.

It is not presumed that such works as these solve the problem of confining shingle rivers in their channels; but they prove a simple and effectual means of diverting a shingle-bearing river from any particular weak point. If a river were embanked throughout its course on both sides in this manner, it would doubtless eventually choke the bed assigned to it and overflow. This, however, will take place with more elaborate and costly protective works to an equal extent.

ON STEEL CASTINGS.*

By Mr. FRANK W. DICK.

From "The Engineer."

In this paper I propose to give a short description of the steel castings made at the Hallside Steel Works by the Terre-noire process. Although steel castings are known, appreciated, and largely used by many engineers, still it is a fact that at present a great number are either entirely unacquainted with them, or have conceived totally mistaken ideas about their nature and merits. Much of this misconception has no doubt arisen from the doubtful success which attended the crucible steel castings brought before the public some years ago.

The principal defects in these castings were hardness and want of solidity, and truly homogeneous metal was a rarity. It was found that by crucible casting

* Read before the Institution of Engineers and Shipbuilders in Scotland.

blowholes were less likely to be formed than in casting on a larger scale by the Siemens-Martin or Bessemer processes; hence, notwithstanding the expense and the many disadvantages inherent to the crucible method, it has been somewhat extensively applied, both in this country and on the Continent. In crucible steel castings a high percentage of carbon is employed to insure fluidity in casting, and the subsequent process of annealing is relied on to make them soft enough for working. In spite of every care these castings are often so hard as to be useless.

The accompanying honeycombed specimen shows what measure of success attended the first attempts at steel casting from the furnace. No matter how strong the material, it is perfectly evident that a casting such as this is quite unsuited for engineering purposes. A further objection which militated against the earlier steel castings was their want of homogeneousness. Hard spots were of frequent occurrence, surrounded by softer material. These spots appeared as lumps when the casting was turned or planed, and made it impossible to keep an edge on the cutting tool. But these objections are fast becoming things of the past, thanks to the Terrenoire process. It is now possible, and is a matter of everyday practice to get castings made of a material which is soft, strong, tough, and free from blowholes, which can be hammered cold or hot, which welds easily, and in fact, which behaves in every way like superior wrought iron, with this difference, that it is very much stronger than wrought iron. It may appear strange that a simple casting should possess toughness equal to or greater than iron which had been wrought; but it has been found from experiments made at Newton (as already noticed by Euverte) that the properties of a piece of steel (free from blowholes) depend entirely on its chemical composition and its molecular condition, and not on the manner in which that condition has been induced, so that if different means can be found to produce similar conditions in steel, the final result is not affected by the method employed. For casting such means are found in annealing and tempering, the effects of which will be noticed later on.

It has been already stated that the difficulty encountered in early attempts to make castings of Siemens-Martin or Bessemer metal was the formation of blowholes. In the Terrenoire process this fault is entirely remedied by the use of a silicide of iron and manganese. "The presence of a trace of silicon is found to have the singular effect of preventing that violent evolution of gas from fluid steel at the moment of solidification," which caused the objectionable unsoundness. In the fluid steel there is carbonate oxide in dissolution. During solidification this gas tends to escape, but is decomposed by the silicon and silica produced, and afterwards a silicate of iron, which would remain interspersed in the steel were it not that the presence of the manganese permits the formation of a very fusible silicate of iron and manganese which passes off into the slag. The metal when run into the mould remains perfectly quiet, and a sound casting is readily obtained, possessing a smooth skin and sharp edges.

A principal characteristic of this metal is its extreme toughness. On the table there are exhibited some turnings taken from a mill pinion, which argue the possession of that quality in the material in a high degree. There are also some bars shown which have been bent cold to an angle which few brands of wrought iron would reach. In one sense this toughness is a drawback—it renders the work of taking off the gates and runners one of extreme difficulty. It is of no use to attempt to "nick" them round and break them off, they must be turned or slotted off. The breaking strain varies according to the nature of the casting, and the subsequent treatment. Plain castings of some size may be made of very soft metal, while more intricate ones require to be made rather harder, but in no case is the metal really "hard," *i. e.*, too hard for tooling. In general the variation does not exceed six tons per square inch, and ranges from 29 to 35 tons per square inch. The extension varies from 36 to 12 per cent. in lengths of two inches, and from about 17 to 6 per cent. in lengths of eight inches parallel. Stronger qualities can be made, but any increase in strength is gained at the expense of toughness. The elastic limit I have

invariably found to range from $\frac{1}{2}$ to $\frac{5}{8}$ the breaking strain.

The ultimate character of the steel depends much on the treatment to which it is subjected after being cast. I do not refer to the practices of long-continued annealing and heating in contact with oxides of iron, often adopted in connection with crucible steel castings, but simply to the effects of heating and cooling in different ways. Before you are three samples of steel taken from the same casting. The first, which exhibits a largely crystalline fracture, shows the steel simply as it is cast; the second, which is much more compact in appearance, has been heated to a cherry red and cooled gradually; the third, which has a very close texture, has (after annealing) been again heated to a cherry red and cooled in oil. Beginning with the casting in its original state, the effect of re-heating and cooling gradually is to greatly increase the toughness and the extension, to increase a little the breaking strain (except in very soft metals, in the case of which it is not much changed) and to decrease a little the proportion which the elastic limit bears to the breaking strain. By re-heating and dipping in oil the breaking strain and elastic limit are increased, the toughness and extension are diminished, and the metal is compacted. It will be noticed that the effect of dipping in oil appears to be analogous to that of hammering; much the same changes are induced. I have here two bars, one 1 inch square, cut from the same casting. One is annealed simply, the other is annealed and dipped in oil. They were tested transversely with 3 feet bearings. The annealed one took its first permanent set with a load of 0.4 tons applied midway between the supports, and finally sunk with a load of 0.7 ton. It has been bent through considerably more than a right angle, and is not broken. The one dipped in oil took its first permanent set with a load of 0.5 ton and sunk when loaded with 0.9 ton, breaking when bent through 90 deg. These bending tests corroborate the results of many tensile tests with regard to the increase of strength and decrease of toughness due to cooling in oil.

The art of steel founding is now so perfected that it is scarcely too much to say that anything which can be cast in cast iron can be cast in steel. The applications of steel are already almost innumerable. From it are made crank shafts, thrust shafts, connecting rods, eccentric rods, cross heads, guides, propeller blades and bosses, and even the nuts for them, gearing of all descriptions—the toothed wheels already cast ranging from a few pounds to as much as twelve tons in weight—carriage and wagon wheels, locomotive bogie centers, rolls and rolling mill gear, anchors, hydraulic cylinders, steam hammer faces and anvil blocks, and so on. It is seldom that a working stress of more than one ton per square inch is allowed to be put on cast iron. Hydraulic riveters of Hallside steel are in daily and satisfactory use under a working stress of 14 tons per square inch. Here, then, we have a material which can be moulded to any shape as readily as cast iron, and which is stronger and tougher than wrought iron. Moreover, like wrought iron it can be wrought under the hammer and welds with facility. It is almost unnecessary to point out the advantages which accrue from the possession of such a metal. The simple process of casting will, in numerous cases, displace the more difficult method of forging. In cases, also, where the engineer is tied to weight—as often instanced in marine engines—it is evident that the use of a material which is at least six or seven times stronger and more reliable than cast iron offers one means of securing lightness without the sacrifice of strength.

I will conclude with one or two examples of the relative durability of cast iron and steel. A cast iron worm in connection with the turning gear of one of the steam cranes in the foundry at Hallside was found to grind itself away in from two to three days. The steel worm by which it was replaced lasted eight or nine months. A driving pinion in the rail mill when of cast iron usually gave way in from one to three weeks and failed through breakage of the teeth. A steel pinion, made to replace one of these, was taken out at the end of two years' continuous work, and then only because the teeth were so much worn that they did not gear properly. Steel is invaluable in rolls which are much cut into by the sections they are intended

for. In plain rolls the surface lasts well. The method of chilling is not used, but the hardness can be increased by increasing the carbon. It should perhaps be mentioned that the shrinkage of steel castings is about 1 inch per foot.

HYDRAULIC MORTARS.

By DR. MICHAELIS, of Berlin.

From "The Building News."

If we admit the hypothesis of the formation of a hydro-silicate of lime, ignoring all accessory processes, we may thereby explain the nature of hydraulic induration. We do not intend to enter here into a full description of the hydro-silicate of lime and its properties, but shall merely examine two of its more salient features.

The calcic hydro-silicate which is found in all hydraulic limes, Puzzolana mortars, and Portland cements, can exist only under water or in a medium saturated with moisture; if exposed to the air, it loses, at ordinary temperatures, water of hydration, and its composition is thereby destroyed. If our hypothesis, that hydraulic induration is mainly owing to the formation of a hydro-silicate of lime, be correct, the above-mentioned property of this silicate will be observable in all hydraulic substances, including Portland cement. It has long been known, with respect to the "Santorin earth," that the mortar produced with this puzzolana (which is chiefly composed of pumice—volcanic lava), loses, in contact with the air, the cohesion it has attained under water. For some years, we have prosecuted investigations in this direction with regard to all kinds of hydraulic substances, and have conclusively established the fact that no cement can retain uninjured its cohesion, otherwise than by being kept in a damp medium.

It is obvious that this fact will be most apparent in the case of pure hydraulic mortars unmixed with sand or other aggregates. Every one will recollect having observed pure or rich hydraulic mortars which showed signs of incipient disintegration, in the form of hair-like cracks.

A second property of this hydro-silicate of lime is its behavior in every respect like a colloid. Its nature is similar to that of the hydrates of silica, alumina, magnesia, and lime (existing in quick lime). It presents the appearance of a swollen gelatinous body, with no tendency to crystallization; at least, in no case in which we have examined this silicate, have we been able to prove conclusively the presence of crystals. The hydro-silicate behaves like a mineral glue, and possesses all the cementitious properties of its constituents; during the process of desiccation, it becomes gradually more compact, and shows, up to a certain point, a constant progression in cohesive strength; finally, it surrenders its water of hydration, when the disintegration commences.

The less compact the hydraulic mortar, the more rapidly will this disintegration take place; the denser it is, the more capable will it show itself of withstanding it. Thus the pure hydro-silicate of lime is destroyed with rapidity; Santorin earth and Puzzolana mortars, within a short period; hydraulic lime and Roman cement more slowly; while, last of all to succumb, is Portland cement. Even this excellent material, if used neat or in large proportions and exposed to the air, cannot last out a single summer; after this period in our own climate (and this is much more notably the case in warm countries), it is found to be covered with a network of innumerable capillary cracks, which hitherto have been generally taken as a proof of imperfect manufacture or careless workmanship, and as being a sign, though an insignificant one, of a tendency to "blow." They are, however, in every case the natural and inevitable results of desiccation, and betoken the commencement of disintegration.

The above remarks will be sufficient to furnish our readers with the key to many hitherto unexplained phenomena; in order, however, to afford every one an opportunity of forming his own judg-

ment in the matter, we shall adduce from our investigations a few experiments which have a more especial bearing on the subject before us.

A sample of Portland cement (Wallsend brand) had lain for five years immersed in water, and during that period had given the following results (every number being the mean of at least ten breakings).*

Age	1	day,	223.73	lbs. per square inch.
"	2	"	245.05	" "
"	3	"	411.75	" "
"	4	"	496.67	" "
"	5	"	465.52	" "
"	6	"	509.62	" "
"	7	"	482.45	" "
"	1	month,	684.41	" "
"	3	"	752 97	" "
"	6	"	1002.29	" "
"	9	"	855.94	" "
"	1	year,	1149.79	" "
"	2	"	847.84	" "
"	3	"	808.30	" "
"	4	"	869.59	" "
"	5	"	962.33	" "

This cement was therefore of excellent quality; nevertheless briquettes of the same cement, which had lain under water for a period of five years, after being exposed to the air for ten weeks, at a temperature of 18° to 20° C. (64.4 to 68° F), showed a strength of only 433.8 lbs. per square inch.

The two portions of one of the strongest of the briquettes broken at 5 years (giving 1,024.1 lbs. per square inch) were dried over chloride of calcium, whereby the following decrease in weight was found to take place:

	Weight.	Loss of Weight.
Air dried,	203.300 gram.	
After 1 month,	185.527 "	17.773 gram.
" 2 "	185.300 "	0.227 "

Thereafter one portion of the briquette (*a*) was kept for five months over chloride of calcium, and then in the desiccator over sulphuric acid; the other portion (*b*) was wrapped in blotting paper, and placed aside in the laboratory.

These investigations were commenced in October, 1878; in both instances the decrease in weight was continuous, and was as follows:

	(*a*)	loss.	(*b*)	loss.
After 3 months,	99.322	—	85.984	—
" 4 "	99.128	0.194	85.990	—
" 5 "	98.724	0.344	85.775	0.209
" 6 "	97.945	0.829	85.703	0.072
" 7 "	97.802	0.143	85.658	0.045
" 8 "	97.570	0.282	85 597	0.059
" 9 "	97.290	0.280	85.495	0.104
" 10 "	—	—	85.353	0.142
" 11 "	—	—	85.165	0.188
" 12 "	95 292	1.998	84.892	0.263
" 13 "	95.042	0.250	84.755	0.137
" 14 "	94.463	0.579	84.260	0.495
" 15 "	94.106	0.357	84.064	0.196
" 16 "	93.507	0.599	84.138	—
" 17 "	—	—	83.437	0.627

The loss has hitherto been constant; the same investigations are being continued.

With the excellent "Stern" cement a series of tests, to extend over a period of ten years, was commenced in January, 1876, with a view to establishing the relative strength of cement tested in a dry and wet condition. The wet briquettes were tested immediately on being taken from the water, those to be broken dry were removed from the water 14 days before testing. While testing the briquettes broken after 30 days (in February) and also those from the first to the fourth year (broken in January) the room was heated.

Age.	Broken Wet.	Broken Dry.
7 days,	777.3 lbs. per sq. in.	—
30 "	844.4 "	707.0 lbs. pr. sq. in.
90 "	958.9 "	902.9 "
180 "	912.1 "	730.9 "
1 year,	925.1 "	623.8 "
2 "	997.7 "	600.9 "
3 "	685.7 "	509.9 "
4 "	947.3 "	396.8 "

Among the numerous tests (over 80,000) which have been carried out in our laboratory, those made neat cement, lime, and puzzolana mortars, which were kept exposed to the air, invariably showed at advanced age signs of incipient disintegration more or less distinct, unless care was taken that the atmosphere in their vicinity was kept saturated with moisture.

The fracture of a cement, injured through desiccation, is so characteristic that the progress of disintegration or loss of strength may be recognized with ease. The appearance which any pure hydraulic mortar presents, if broken at a certain age, is invariably of a "shelly"

* We are of opinion (See also "Zur Beurtheilung des Portland Cements," Polytechnische Buchhandlung. A. Seydel, Berlin, 1876) that the decrease in tensile strength after the first year is merely apparent, and that it is due to a change in the molecular structure. In course of time the structure of cement gradually approaches in appearance that of porcelain; its elasticity diminishes, but its resistance to pressure increases, or the relation between the tensile and the crushing strength becomes altered in favor of the latter, the cement becoming more brittle.

character; a cement which has been injured by desiccation shows, on the contrary, a fracture of a more serrated nature.

Investigations with the object of ascertaining the degree of humidity of the atmosphere, beyond which hydraulic mortars retain their water of hydration, are at present in course of prosecution. By another series of tests we are endeavoring to establish the extent to which mixtures of hydraulic materials with sand, or other aggregates, are capable of withstanding the destructive effects of desiccation.

In analogy with the behavior of quicklime, and in accordance with the colloidal nature of the calcic hydro-silicate, the contraction is less injurious in its effects the poorer the mortar.

We have endeavored to show how the hydro-silicate of lime existing in hardened cement becomes, by continued separation of its water, gradually more dense, and, although in its separate particles becoming harder, is eventually destroyed through the fissures produced by contraction, which then become the cause of the total disintegration of the mass, under the changing influences of heat and cold, and more particularly of frost.

If it be true that the destruction of cement is due merely to contraction, causing interruption of continuity of the mass—in short, to those capillary fissures—it must follow that the well-known means for preventing contraction, especially the admixture of sand, will enable cement to escape these disastrous results.

It is understood that we speak here only of cements of unexceptionable quality, and their deterioration when exposed to the action of the atmosphere. The disintegration of cement mortars kept under water in a moist condition arises from imperfections in the cement, in most cases from actual "blowing," and in such instances the fissures produced are appearance of a totally different character.

If briquettes of neat cement and of cement and sand mixtures, which have undergone the hardening process for a considerable period immersed in water, and are perfectly intact, and have attained a high degree of strength, be exposed for a lengthened period to a process of desiccation, either in the desiccator over sulphuric acid or chloride of calcium, or in the atmosphere at a temperature between 60° and 120°, C. (140° to 248° F.), in every case the neat cement will be observed eventually to be covered with fine capillary cracks. The larger the size of the briquette the more rapidly and distinctly will these cracks make themselves apparent. In the case of tensional briquettes, even in the small one-inch section fiddle or wedge-shaped pattern, considerable cracks may be observed in the direction of the long axis of the briquette. The strength is found to be affected more or less, according as these cracks take place more or less nearly at right angles to the line of tension. Even very distinct cracks, when in the direction of the strain, exert little or no influence on the tensile strength.

In many cases no sign of capillary cracks can be discovered, even on a very close external examination of such dried briquettes; the characteristic serrated fracture on breaking reveals, however, at once, the latent pressure, so to speak, of contraction.

In the case of cement and sand mixtures, the writer has not, for a long time, observed any such phenomena when the cement was of good quality, and mixed with not less than two parts of sand; even with mixtures of 1 : 1, if worked up sufficiently stiffly, cracks are very seldom apparent in small briquettes.

The larger the size of the object which is prepared from cement mortar, and the greater the strain to which it will be subjected, the smaller should be the proportion of cement used. On this account also, it is in the highest degree requisite that cement be ground much more finely than has hitherto been customary. If, for example, a manufacturer of artificial stone employs 1 part of cement, ground to the ordinary degree of fineness, with 2 or 3 parts of sand, he might, with a more finely-ground cement, such as would pass through a sieve with 32,000 meshes per square inch and leave no residue, use 5 or 6 parts of sand; the article produced would attain the same strength after the same length of time as that prepared with a much larger proportion of coarsely-ground cement, and would, at the same time, exhibit a much better appearance and remain free from capillary cracks.

In order to study the effect of desiccation on mixtures of cement and sand, we have carried out, among others, the following series of tests, the briquettes employed being of 5 square centimeters sectional area:

1. The same cement as that of which the strength, up to the age four years, is given above, and which was thin, was tested neat, in the one case direct from the water, in the other, after lying 14 days exposed to the air, was made up with one, two, three, and four parts by weight of sand and tested, in the case of those under "A" immediately on being removed from the water, those under "B" being permitted to remain 28 days exposed to atmosphere.

The mean, in each case, of 10 briquettes, furnished the following results in lbs. per square inch:

	1:1		1:2		1:3		1:4	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Age								
180 days	603.1	754.5	462.3	637.2	347.0	583.1	285.9	450.8
1 year	635.9	775.2	487.7	611.6	368.8	458.1	302.8	406.6

Thus it will be observed that in no case did a decrease in strength take place through the briquettes being dried before breaking; but, on the contrary, a considerable advance in strength, and that from causes of which I shall hereafter treat.

2. Briquettes of one part cement and one part sand, which had been undergoing induration under water for a period of 3½ years, were broken as follows:

a. Directly on removal from the water.

b. After four weeks' air drying.

c. After 27 days' air drying; the briquettes were then re-immersed in water: tested directly from the water.

d. After 21 days' air drying, then seven days re-immersion in water: tested directly from the water.

e. Seven days' drying at 130° to 140° C. (266° to 284° F.).

f. Seven days' drying at 130° to 140° C. (266° to 284° F.). Then one day re-immersed in water: tested directly from the water.

g. Seven days' drying at 130° to 140° C. (266 to 284° F.). Then seven days re-immersed in water: tested directly from the water.

The following are the results, each number being the mean of ten breakings, in lbs. per square inch:

a	*b*	*c*	*d*	*e*	*f*	*g*
411.6	672.8	484.3	480.0	588.1	428.1	374.1

It will be observed that *b* to *g* inclusive, which were subjected to a process of desiccation, have suffered no diminution in strength (the insignificant variation between *a* and *g* is such as occurs between briquettes treated identically); it is well known that a certain slight increase in strength is always occasioned by the formation of carbonate of lime; this, however, may be left entirely out of account in view of the fact that all cements, sand, mortars, as also all common bricks (capable of absorbing a considerable amount of water) porous sandstones, &c., present, in the dry state, greater resistance to the separation of their molecules.

The series of tests, *c*, *d*, *f*, and *g* afford ample proof of this.

3. A cement mortar of one part of cement and five parts of sand, showed, after 20 months' hardening under water, an average strength of 349.2lbs. per square inch. Several of the briquettes were taken out of water, after a period of 12 months, and immediately placed in a desiccator; they were then dried for eight months over sulphuric acid, thus securing the elimination of all influence of carbonic acid. These briquettes broke, after 20 months, at an average strain of 490.3 lbs. per square inch.

These experiments prove, in a conclusive manner, that mixtures of cement and sand do not become disintegrated like neat cement mortar; the addition of the sand removing effectually any tendency to contraction, and the consequent formation of fissures; thus, the continuity of the mass is nowhere interrupted. On the other hand, we may safely conclude that the presence of these contraction fissures is the sole cause of the disintegration of pure and rich cement mortars when exposed to the action of the air.

The foregoing remarks will readily explain the complete fiasco which artificial stone has always been, when pure cement, or large proportions of the same, have been used.

ON LIGHT RAILWAY LOCOMOTIVES.

By HERR VON BORRIES.

Abstracts of Institution of Civil Engineers.

THIS is a continuation of an article already abstracted.* Referring to the table of leading dimensions in that article, the author states that the figures given for heating surface, grate surface, and capacity for water, are not to be considered as the greatest possible, and as capable of no further improvement; they are rather figures which can be and ought to be attained under all circumstances. At the same time increase in such particulars—*e. g.*, in size of boiler—is not the first consideration in light railway engines; for these the point of chief importance is security against damage of all kinds, which can only be attained by ample strength in constructive parts. In capacity of water tanks and coal bunkers, however, there is more room for improvement, and it is considered that with the best construction of engines, having the leading dimensions and weight given in that table, the water tanks may hold 0.16, 0.14, and 0.12 cubic meter per ton weight of engine, according to the gauge, while the coal bunkers may hold 0.05 to 0.04 cubic meter per ton weight.

On the other hand, the haulage weights given in the second table are to be taken as the maximum which can be attained in favorable weather; wind, rain, &c., will reduce the amount, and it will be better to take 90 to 95 per cent. of the figures given as the average for practice.

The author then proceeds to discuss the application of the compound system to light railway engines, which he considers to be necessary, if the pressure is to be raised above 150 lbs. per square inch. Its special recommendation for light railways is the saving in fuel, which is here of great importance, and compound engines on the author's system are not really more complicated than the ordinary kind. The compound engine, if built to the leading dimensions of Table I., will be somewhat heavier on account of the larger cylinders, &c.; but, since it will use less water and coal, the necessary reduction in weight may be effected by reducing the space for these, the boiler, &c., being kept as before. The cut-off in the small cylinder should not be at more than half stroke, giving 1 to 0.26, or about 4 to 1, as the grade of expansion in the two cylinders jointly; which gives a mean pressure of about 90 lbs. on the large piston. The volume of the large cylinder will then be about $2\frac{1}{4}$ times the volume of the cylinder specified in the table of dimensions, and as this is too large, the stroke must be lengthened. This leads to the following table:

CYLINDER DIMENSIONS, COMPOUND ENGINES FOR LIGHT RAILWAYS.

	(*a*) 4 feet 8½ inch gauge.		(*b*) 3 feet 3⅜ inch gauge.		(*c*) 2 feet 5½ inch gauge.	
Number of axles	2	3	2	3	2	3
Weight of engine, loaded, tons	18	27	15	22½	7½	11⅓
Diameter of small cylinder, inches	11.4	13.8	10.2	12.6	7.5	9.1
" large " "	15.7	18.9	14.2	17.3	10.2	12.6
Stroke, "	22.0	22.0	18.1	18.1	13.4	13.4
Wheel diameter, "	38.6	38.6	31.5	31.5	23.6	23.6

The adhesion-weight, and therefore the power of these engines, is the same as those of the corresponding type in the former tables.

The author next considers locomotives in which the adhesion-weight is artificial-

* *Vide* Minutes of Proceedings Inst. C.E., vol. lxiii. p. 392.

ly increased; the object of course being to enable the engine to haul a greater train load on a given incline than that shown in the second table. For this purpose part of the train load is placed on the engine itself, and thus becomes available by adhesion for hauling the remainder. As the capability of the boiler cannot be further increased, the speed on any incline will be lessened in proportion to the increase of the adhesion. The limit here will be when the whole train-weight is placed on the engine, in which case it could theoretically surmount a gradient of 1 in 7½. It is another question whether this plan is advisable, and such applications have at best a very limited field. The ordinary plan is to place upon the engine the space for passengers and luggage, leaving goods and minerals to be drawn by separate wagons. Since lines with steep gradients have commonly sharp curves, the steam-carriage is generally composed of a body resting on two bogies. The engine rests on the front bogie, then comes the luggage compartment, and behind this the passenger compartments. It is best to fix the boiler rigidly to the front bogie, but to unite the carriage part to it by a movable attachment, so that the engine may be separated from it when going into the shop for repairs. All the steam-carriages hitherto built have an engine only on the front bogie, but there is no reason why there should not be one on the hind bogie also. It would then appear specially advisable to adopt Mallet's compound arrangement, using the front bogie for the small and the hind for the large cylinder, the intermediate pipe serving as a receiver. The author, however, considers this arrangement too complicated and expensive, entailing a large cost in fuel and repairs. He would prefer a rack engine where the gradient was so steep as to suggest this arrangement. It may be assumed that for passenger traffic the speed on the steepest incline should not be less than six kilometers an hour, and, since the engine by itself would go at double that speed, there is no advantage in raising the adhesion weight beyond twice that of the engine. The front bogie will then carry two-thirds of the total weight, and the hind bogie one-third.

To consider the advantages and disadvantages of the steam-carriage system, it should be compared with a separate engine doing the same work. It will then be seen that the advantage of the former lies merely in its giving a lighter and cheaper engine; while the disadvantages are the reduced speed on the gradients, the greater wear on the carriage, and the increased difficulty in turning and shunting. Hence it should only be used where the gradients are steep, say above 1 in 30, and its field is probably limited. The dimensions, &c., will be similar to those in Table I., except that the boiler will be about half as large. It appears that two men are sufficient to manage such a carriage, but both must be qualified to drive, and there must be a door between the engine and the passenger compartment.

The author next considers the type of engine required for working local traffic on main lines in omnibus trains, as they are called. Although these engines are not for light railways, they are practically of similar construction, since the object is to work the local traffic in the very cheapest manner, and separate from the through traffic. The heavy engines and carriages, suited to the high speed, &c., of the through traffic, are out of place in local traffic. For local passengers cheapness and frequency of trains are the great recommendations, and the rolling stock must be altered accordingly. The speed on the level may be taken at 30 to 40 kilometers per hour. There are two cases to be considered according as the traffic is (1) between two ordinary stations; (2) suburban traffic in large towns. For the first the author recommends the trains to consist of an engine, a mail and luggage van, a mixed second and third-class carriage, and a fourth-class carriage; in the second case mixed second and third-class carriages of special construction are recommended. In both there should be continuous brakes, and communication throughout the length of the train.

Steam-carriages have been applied for this purpose, as well as for light railways. The advantage is that they save the buffing and draw gear, amounting to a weight of 500 kilogrammes per carriage. On the other hand a steam carriage cannot go backwards, but must be turned at each terminus, and the dead weight is

always the same, as a carriage cannot be detached. Again the detached carriages generally run double the distance of an engine, and this advantage cannot be obtained with a steam carriage. For the sake of engine repairs the carriage and engine part are generally made separable, but this entails extra complication.

It thus appears there are few circumstances in which the steam carriages are to be preferred. A separate carriage on a main line will weigh about 8 tons, and will acommodate 40 persons, if constructed as lightly as possible. If then the maximum number of passengers per train is less than 40, the steam carriage may be preferable, but it should not have more than four wheels.

It was stated before that an ordinary light railway engine will make full use of its adhesion only at a speed of 12 kilometers (7 miles) per hour. For a local traffic engine this may be raised to 15 kilometers (9 miles) per hour by means of a higher evaporative duty. But this speed is far too low for local traffic, even on the steepest gradients. Hence even the separate engine can never use its whole adhesion weight, far less does it need any increase of it, and this seems to settle the question against the steam carriage.

The construction of separate locomotives need, therefore, alone be considered. The weight of well-constructed tank locomotives for a standard gauge is given by the formula $5+0.3$ H tons, where H is the heating surface in square meters. This formula is derived from the experience of Krauss & Co. and Herschel & Son, but applies to this case, where an engine of the greatest power is wanted, more than to light railways, where cheapness and durability are the first considerations. Taking the best construction, which is to have two driving wheels only, carrying 0.6 of the total load, the power of the engine is represented by $138\times0.6\times(5+0.3\,H)\times1,000\times v$, where v is the speed in kilometers per hour. On the other hand the total performance of the steam per hour, allowing 30 kilogrammes to be evaporated per hour, is given by $\frac{3,100\times30\,H}{1,065}$ taking the engine friction at 6.5 per cent. Equating these two together results in a formula for v which gives:

Heating surface..sq. mtrs.,	10	20	30	40	50
Total weight.....tons,	8	11	14	17	20
Speed, kilometers, pr. hour,	4	20	24	26	28

Since these velocities are as low as would be admissible on a line with gradients of 1 in 100, it follows that two driving wheels are sufficient, and this is confirmed by most of the engines for such lines being so built. Where the gradients are above 1 in 100 the construction would be somewhat different. The advantage of having no coupling rods is that the front axle may be put before the cylinder, and the hind axle far back, so that a good wheel base can be obtained with a short boiler. The following table gives the leading conditions for five classes of engines for local traffic:

LOCAL TRAFFIC ENGINES.

Weight loaded.....tons.	8	11	14	17	20
Adhesion weight..... " .	4.8	6.6	8.4	10.2	12
Heating surface.....sq. meters.	10	20	30	40	50
Grate " .... " .	0.2	0.4	0.6	0.8	1
Steam pressure.....atmospheres.	12	12	12	12	12
Diameter of driving wheels... .....mm.	980	980	1,130	1,130	1,330
" cylinders..... ..... " .	180	200	240	260	280
Stroke..... " .	300	360	400	400	500
Contents of tank.....cub. meters.	1.3	1.8	2.2	2.7	3.2
" coal bunkers..... " .	0.48	0.66	0.84	1.02	1.2
Wheel base.....mm.	2,500	3,000	3,300	3,500	3,800
Tractive force (without friction).....kilog.	600	880	1,120	1,360	1,600
Minimum speed.....kilometers per hour.	15	20	24	26	28
Compound engines, stroke.....mm.	340	400	440	440	500
" " diameter of small cylinder ..... " .	180	200	240	260	290
Compound engines, diameter of large cylinder ..... " .	250	280	330	360	400

THEORY OF THE ACTION OF RAILWAY BRAKES.

By E. PERRON.

From "Organ fur die Fortschritte des Eisenbahnwesens," for Abstracts of the Institution of Civil Engineers.

THE author first gives the equations for a heavy wheel moving forward on a rough horizontal plane, and at the same time turning round its axis with given angular velocity, and points out that if this given angular velocity be not originally such that the linear velocity of the periphery equals the horizontal velocity of the wheel (in other words, such that the wheel rolls on the plane) the effect of friction will speedily cause it to assume that particular value. He then takes the actual case of a railway vehicle acted on by a brake, and points out that the effect of the frictional resistance of the brake block is to produce an equal and opposite frictional resistance between the rail and the wheel, and that it is this latter variable resistance which is the real external force tending to stop the vehicle; the brake-block friction must be treated as an internal force. He then forms the ordinary equations for expressing the linear and angular acceleration of the wheel in terms of the applied forces, and from them deduces two ex pressions for fX, the frictional resistance between brake block and wheel, one of them in terms of the time, the other in terms of the distance which is passed over by the wheel from the first application of the brake until it comes to rest. (These expressions, however, assume that the co-efficient of friction between brake block and wheel is always the same, and will require correction in order to take account of the fact now established, that this co-efficient varies with the speed, and is therefore never the same at any two moments during a stop.) The expressions for X show that, when the wheel is stopping, the frictional resistance of the block is greater than that of the rail by an amount which is, in fact, the force expended at each moment in destroying the *vis viva* of rotation in the wheel. This excess, however, is insignificant, amounting, in the case of an ordinary railway wheel and axle, to about 20 lbs.

The maximum effect of a brake is attained when the rail friction which it calls into play is the utmost which the rail is capable of exerting, *i. e.*, is equal to the weight on the rail multiplied by the co-efficient of friction between rail and wheel. Any greater amount of brake friction can only be expended in stopping the rotation of the wheel, *i. e.*, in causing it to slide. The value of this maximum pressure is easily obtained from the general equations. The high value of this maximum appears to conflict with the well-known fact that even the heavily-loaded wheels of a tender can often be skidded by means of ordinary hand brakes, applied by a single man. This the author considers to arise from two causes (1) the great mechanical advantage given by the screw gear of an ordinary hand brake, amounting to about 60 to 1; (2) the fact that the surface acted on between wheel and block is very much larger than that acted on between wheel and rail, and that according to Coulomb the total friction for a given pressure increases with the area.

The author then goes on to consider continuous brakes, and lays down the five following essential requisites for a good brake:

(1) Before everything else, simplicity of construction, combined with lightness and mobility in the parts, for rapid working.

(2) The brake to be controlled either by driver or guards.

(3) The action to be automatic, so that in case of accident the brakes shall put themselves on.

(4) The brake to be available even when the train is not completely made up.

(5) The working power to be always ready, and easily increased or diminished, so that it may be used for controlling the train in ordinary running, as well as for stopping it altogether.

The author finally discusses the Heberlein brake, and observes that while it is

seen at once to fulfill the first four conditions, it is otherwise with the last, since it seems impossible that a comparatively small friction roller should be able to produce the great pressure on the blocks requisite to elicit their maximum effect. He therefore gives a theoretical investigation to show that by varying the angle which the hanger of the friction roller makes with the horizontal, a strain of any required amount can be brought on the chains which actuate the brake blocks.

THE CONSTRUCTION AND WORKING OF LIGHT RAILWAYS ON COMMON ROADS.

By HERR BURESCH.

Abstracts of Institution of Civil Engineers.

THE conditions to be satisfied, if a road is to be utilized for a light railway, are (1) that it should be wide enough for both kinds of traffic, (2) that the gradients, &c., should be suitable for a railway of the kind intended, and (3) that the direction of the road should suit the traffic to be conveyed on the railway, without making too great a circuit. As to (1), if the road is to be laid with a railway of normal gauge, requiring 13 feet width to itself, the total width between the ditches should not be less than 27 feet, and had better be 33 feet. If the gauge is $\frac{3}{4}$ meter or 2 feet 6 inches, the minimum width may be 20 feet. As to (2), the gradients should be as light, and the curves as few and easy as possible, in order that the engines may not be too heavy.

The most important question is the saving which will be effected by the utilization of the road. To answer this it is necessary to estimate, under its various heads, the cost of a light railway not laid on a road, but taken from point to point by the easiest route, and then to consider how far each item will be reduced by laying it on an existing road. It is assumed that no special expenses, such as paving the railway for horses, are required, and that the general conditions are the average ones of an ordinary hilly country. The various items of cost and reductions, due to using the road, will then be about as follows, (see Table, next page,) each given as a percentage of the total cost in the case of a light railway.

It thus appears that the saving by use of the road may be put at one-third, of course on the assumption that the railway pays nothing for the occupation of the road. Financially, therefore, the advantage is great; it remains to consider the other elements of the question. The advantages are as follows: (1) The arrangement having once been made with the proprietors of the road, the long and costly proceedings for the purchase of land are avoided, and the line being laid on a public road no private rights are interfered with. (2) The preliminary works are much lightened, inasmuch as the trace of the railway is already fixed almost throughout, and the bridges and culverts are arranged. (3) The materials required can be cheaply and easily brought to the spot by the road. (4) The existence of the road makes the maintenance of the line cheaper and easier from the first, and the old roadway forms a better foundation than new earthwork can. (5) The watching and cleaning of the line is cheapened by using the same set of men for road and railway. (6) As the road passes right through the towns and villages on the route, the stations can be placed where most convenient for the public, and for the railway. (7) Branches to works, yards, &c., can be made at the least possible cost, and the station yards can thus be simplified.

Whilst these advantages are undoubtedly great, the following disadvantages are also to be considered:

(1) The unfavorable nature, in general, of the gradients and curves, especially on old roads and in hilly countries, seriously diminishes the advantage of using the road, and sometimes wholly destroys it. A saving in construction is dearly purchased if disproportionately heavy engines have to be employed for work-

Item of cost.	Cost for railway.	Saving by use of road.
	Pr. ct.	Pr. ct.
A. Purchase of land..... (The 5 per cent. will be spent in necessary diversions at villages, at steep inclines, and at sharp curves, for stations, sidings, &c.)	13	8
B. Earthwork and ballasting.... (It is assumed that sharp gradients and curves are got over by diversions from the road, so as not to increase unduly the cost of working.)	14	8
C. Bridges and culverts..... (It is assumed that the existing works can be utilized without much enlargement.)	8	6
D. Permanent way..... (Here there can be no saving, but probably the reverse, since wherever the railway crosses the road paving and tramway rails must be used.)	27	0
E. Track laying..... (At crossings, &c., some expense for maintenance must always be expected.)	2	1
F. Fencing..... (It is assumed that there will be no fence between the road and the railway; but some fencing will always be required at diversions, &c.)	2	1
G. Signals.....	1	0
H. Buildings..... (It is supposed that for stations, &c., existing houses will mainly be utilized.)	11	5
I. Rolling stock..... (Here there will be no saving, but rather an increase, if the gradients are more severe and require heavier engines.)	12	0
K. General expenses..... (A line laid on the road will not require so much allowance as usual for contingencies.)	10	4
Total.....	100	33

ing. The modern use of steel rails does not remove this difficulty. The cost of working increases more rapidly than the weight of the motor, because of the small load which the latter is able to haul on steep inclines. Economical working is only possible with favorable gradients and curves. If this point is neglected, especially on lines with small traffic, the expenses are likely to exceed the receipts. Should these unfavorable conditions occur only at a few points in the road, they should be avoided by diversions or circuits. Where the road passes through villages, very sharp curves should be avoided, even at the expense of crossing the road, a process which is rendered easy by the use of sunken tram rails. Steep gradients, if short, or rapid undulations, are not of much importance; since, with the slow speed and light trains of such railways, they can be easily surmounted.

(2) The danger of setting fire to buildings, &c., should be carefully considered before the railway is commenced.

(3) The same applies to fencing between the railway and the road. If this is required, it would probably be better to lay an independent line.

(4) The speed on a common road must be lower than is usual with light railways. Although the road traffic commonly falls off when the railway is opened, this may not happen if the road is largely used for driving cattle, and other agricultural purposes. In such cases it is generally required that the exhaust shall not be visible or audible, and often that the train shall stop when passing cattle, &c. The difficulty of seeing far ahead on a common road also prevents a rapid speed. Assuming 12 miles an hour as the normal speed for a light railway, that on a common road will not exceed 9, which is not much greater than that of ordinary carriages.

(5) The risk of accident to men and cattle is of course much greater than on a railway.

(6) Opposition may be expected from the public who use the road, and who, not understanding the advantages of the railway, resent its intrusion. This is sure to take the form of petty annoyances, which may seriously hinder the success of the line.

It should be added that an intermediate course may often be possible, *e.g.*, to lay the line on the other side of the road fence, or immediately above the ditch; or sometimes in one of these positions and sometimes on the road itself.

It thus appears that the question of laying a light railway on a road must be decided by a careful balancing of the *pros* and *cons*. If the need of the railway is urgent, and the capital for an ordinary line hard to procure, the road should receive the preference. If the embankments of the ordinary line could

be used for reclaiming waste lands, as may often be the case in marshy valleys, this would be an argument in its favor, and similarly if the laying of the line upon the road met with great opposition in the district.

In Part II., p. 52, follow two supplements to the above by Herr Tull and Herr Alken, co-referees with Herr Buresch. The former remarks that several Prussian provinces have laid down conditions as to the laying of railways on common roads. Under these regulations the top of the rails must be level with the surface of the road, and gradients steeper than 1 in 25 cannot be utilized. It is, however, allowable to make the formation level of the railway higher or lower than that of the road if required. The ordinary high roads of 33 feet total breadth, of which 21 feet are paved, are not considered wide enough for railways of standard gauge. This might well be relaxed on many roads where the traffic is small. It is further ordered that engines working on such lines should be fitted with the best known appliances for noiseless working, and for preventing the escape of smoke and steam, and should have the mechanism hidden from view. This would seem necessary only where the road is bordered by buildings, and in such parts the railway will generally take another course. On the open road such restrictions seem out of place, since even horses, as is well known, get quickly accustomed to ordinary locomotives. It will much hinder the use of such railways by main lines, with which they may communicate. Lastly, the Railway Company has to place caution money in the hands of the owners of the road, to be used in taking up the railway should this ever become necessary. The amount is made proportional to the total capital of the railway, whereas it should be proportional to the cost of the permanent way alone. The conditions on the whole are far too favorable to the owners of the road, who should be simply considered in the same relation as the owners of property through which a line passes, and for the same reason, viz., that the construction of such lines is to the public interest.

Herr Alken concurs in the view that the relations between road and railway should be settled by law, and thinks the formation of such railways, whilst of great moment to the public and to the main lines, might also be made of service to the owners of the road. He suggests that the repair and working of the road and railway should be placed under a common Board, who should also collect the dues on both, and divide them in some fixed proportion. There would thus result a considerable saving in wages, a simplification of arrangements, avoidance of all friction and competition between the two bodies, and combined action towards customers and the public. Many of the restrictions placed on the railway might then be removed, and compromises come to upon others.

THE DUPUY DIRECT PROCESS.

The attention of the scientist as well as the practical iron maker, has long been directed to the very desirable results of producing malleable iron direct from the ore without the necessity of first melting it into pig iron, and then puddling the pig. Malleable iron can be thus made, and has been so produced, to a limited extent, in India, and other countries for many years; but, we believe, until the invention of the Dupuy process, no practical commercial success had been achieved, by which any considerable quantities of malleable iron could be turned out. The process of Mr. C M. Dupuy is so simple, and yet so certain that it can hardly fail to engage the attention of practical ironworkers as an economy which it is impossible to ignore. We therefore propose to place before our readers the latest improvements in this process. Reduced to a simple statement of plain facts, it consists in grinding the iron ores, or other iron-bearing materials, such as tap cinder and droppings from puddling furnaces, iron and steel scale, blue billy (or purple ore) into the condition of a coarse sand, and mixing with

the pulverized material from 15 to 18 per cent. of coal dust, together with a certain quantity of aluminous clay, lime, and salt. These pulverized substances are intimately mixed together in a mortar mill, or similar machine, and in a thick moist condition. From thence they are taken to a machine similar to that used in making drain pipes, where they are pressed into pipes or moulds of about 16 inches in length by 7 to 8 inches diameter, and having walls from 2 to 2¼ inches think. These pipes, when thoroughly compressed, are taken from the machine, and charged on their ends into a heating furnace; being spaced about 3 or 4 inches apart on the furnace bottom. The heat is properly applied, and in about two hours the metal in the mixture is brought to nature, and can be balled, hammered into blooms, and rolled directly into bars, all in the same heat, and with the limits of waste not exceeding 15 to 20 per cent. of the metallic value of the iron which the ores or iron-bearing material contains.

The malleable iron thus produced has been found to be equal, if not superior to, bar iron made by the puddling process, whilst the cost of first reducing the ore into pig iron is thus saved. By means of the aluminous clay, lime and salt (applied in proper proportions and depending on the analysis showing the constituent elements of the ores) the phosphorus, sulphur and other impurities are so carried off in the slag, that a greater purity of the iron is secured than by the ordinary method of puddling. We are informed that the most recent working with this process shows that from 3 tons of puddle tap cinder containing 17.710 of silicon and 1.960 of phosphorus, one ton of bar iron was produced, which yielded an analysis 0.26 of silicon and 0.38 of phosphorus. This charge was reduced and rolled into bar within three hours and all in one heat. With old Bed Champlain ore largely carrying phosphorus, which was reduced and rolled within the same time, the analysis of the bar showed only 0.16 of phosphorus. The utilization of tap cinder by this process would appear to be an assured fact.

The economy of the process is shown by its simplicity, and the advantages derivable are stated to be as follows: In the first place all expensive plant is avoided, as the reducing furnaces, even where specially constructed (and which may not always be necessary) do not exceed a cost of £300 each. Such furnaces are capable of yielding from 4 to 5 tons of malleable iron daily when worked by two men. Two furnaces can be worked at the same time, and with much less labor than by puddling. The grinding, mixing and moulding machinery are quite inexpensive. The entire saving of the cost of first reducing the ore into pig is thus effected. The rapidity with which malleable iron is formed proves a great saving of fuel in the reduction, and necessarily in the cost of the bar iron. Under this process, by which the intimate commingling of the various atoms of the mixture is secured, the iron of the ore is stated to be dephosphorized, desulphurized and desiliconized in the reduction, and thus the purity of the malleable iron produced makes it eminently suited for the manufacture of steel by the crucible as well as the open hearth or Siemens-Martin process, whilst the cost of the iron in its malleable state is, under favorable conditions, said to be even below that of the Bessemer pig iron used in many of the open-hearth steel furnaces. In using the tap cinder and droppings from puddling furnaces, as also the scale from rolls and hammers, a great saving results to mill owners, as from each three tons or less of these comparatively waste products, 1 ton of good bar iron can be obtained, at a cost of about two-thirds of the ordinary selling price of the puddled bar.

It is worthy of remark that by these late improvements Mr. Dupuy entirely does away with the use of the sheet iron canisters formerly deemed by him absolutely necessary to preserve the iron ore from the waste of oxydization. This important item of expense being saved (some 15s. to 20s. in the cost of each ton of bar iron produced) and the time necessary for the reduction in the furnace being now shortened one-half, mill owners will no doubt readily appreciate the value of a system which will enable them at a very trifling outlay to work up into profitable bar iron a material heretofore deemed by them almost as a waste product, if not even a serious charge upon their profits by its rapid accumula-

tion. The Dupuy process is in active operation in the United States of America, and we have recently examined some excellent specimens of iron manufactured in England upon this system, and which give excellent results. We saw these samples at the office of Mr. Philip S. Justice, of 14 Southampton Buildings, Chancery Lane, London, who, we understand, represents Mr. Dupuy in this matter, and is introducing the system into England.

UNIFORM STANDARD TIME.*

By SANFORD FLEMING, M. I. C. E.

THE question which I have been requested to bring under the notice of the Convention, although not strictly of an engineering character, yet, from its nature, cannot fail to be of interest to the members of the American Society of Civil Engineers, many of whom have taken a prominent part in establishing the great lines of communication on this continent. To the large number of its members connected with the administration and development of the gigantic railway system extending between the two oceans, which in length are but little less than 100,000 miles, the subject becomes one of vital importance.

The occasion strikes me as peculiarly appropriate for submitting for your consideration the subject to which with your permission I will briefly refer. The Society meets for the first time beyond the limits of the United States, to find in the Dominion of Canada a cordial welcome. Many of its members in attending this Convention must have traveled long distances, and have experienced, in one way or another, some of the difficulties it is proposed should be removed.

The definition of civil time and its scientific determination for railway, telegraph and all ordinary purposes, is a problem to which a solution is imperatively demanded by the present condition of civilization.

The question has been examined by the American Metrological Society, New York; the Imperial Academy of Science, St, Petersburg; the Royal Society, London, England; the Canadian Institute, Toronto, and other scientific bodies.

Its importance has been fully admitted and expressions of opinion have been obtained as to the means of overcoming the difficulties which are experienced.

The citizens of the United States and the subjects of Her Majesty the Queen occupy together the greater portion of North America. The most friendly relations exist between us, for, in the main, we are substantially one people, living under different governments, with laws and customs essentially identical. On all sides we are satisfied to remain separated by our political affinities, having distinct theories and beliefs with respect to systems of government. But science, like every noble virtue, knows no national boundary. In this brief note I can recognize none. In alluding to matters which equally concern the United States and Canada, I shall refer simply to this country or to this continent.

As the continent extends across 105 degrees of longitude, and an individual at the western limit finds himself seven hours of recorded time behind another individual at the extreme eastern side at the same moment of absolute time. Much of the intervening country is but thinly settled, but railways and telegraphs traverse from ocean to ocean, and we have every gradation of difference of time between the extreme limit of seven hours.

According to the system of notation which we have inherited from past centuries, every spot of earth between the Atlantic and the Pacific is entitled to have its own local time. Should each locality stand on its dignity it may insist upon its railway and its other affairs being governed by the time derived from its own meridian. The smaller and less important localities, however, as a rule, have found it convenient to adopt the time of the nearest city. The railways have laid down special standards which vary as has been held expedient by each separate management. In the whole country there is, so far, an irregular

*A paper read at the Montreal Convention of the American Society of Engineers.

acknowledgment of more than one hundred of these artificial and arbitrary standards of time. The consequences of this system are unsatisfactory. They are felt by every traveler; and in an age and in a country when all, more, or less, travel, the aggregate inconvenience and confusion is very great; and it will be enormously multiplied as time rolls on. If the system already results in difficulties to trouble our daily life, and to lead to embarrassments which often occupy our courts of law; which, indeed, too often are the cause of loss of life, what will be the consequences in a few years, when population will be immensely increased and travel and traffic indefinitely multiplied, if no effort be made to effect a change.

The societies I have mentioned, after careful examination, have united in the opinion that a satisfactory change cannot be made too soon, and they have adopted resolutions pointing to a general uniformity and thorough accuracy in time reckoning. They believe that the course they have recommended will greatly facilitate the daily transactions of business men, greatly increase the safety of the traveling public, and immensely benefit the whole community.

It is proposed that the community unite in an effort to simplify the system now in use by reducing the number of time standards to a minimum, by substituting for an indefinite number of irregularly established and purely local standards, a few main, or, as they may be termed, continental standards, each one having a fixed and well known relation to all the others. It is proposed to have these standards established and maintained by governmental authority; to have them regulated with precision through a common central observatory, and through these standards it is proposed to keep every town, city, railway and steamboat clock throughout the land as nearly as practicable in perfect agreement.

The plan of arrangements favored by the Metrological Society, New York, and the Canadian Institute, Toronto, is to have the standards so established that they will be exactly one hour apart; that is to say, while it would be nine o'clock at one standard it would be eight o'clock at the next to the west, seven o'clock at the following, and so on, by steps of exactly one hour. There would be no difference in the minutes and smaller divisions of time. If the time be ten minutes or thirty minutes past the hour at any one point, it would at the same instant, in absolute time, be ten minutes or thirty minutes past some hour at every point. The hours themselves only would differ, and they would differ only in designation according as the localities were east or west. At the same instant of absolute time every clock in the country would strike either one hour or another, the minute and second hands would always and everywhere be in perfect agreement.

It may be known to gentlemen present that the officers of the United States Signal Service, have evinced a deep interest in the question and in the efforts to establish uniformity, accuracy and simplicity of system throughout the country. General Hazen, Chief Signal Officer, Washington, has expressed his earnest desire to contribute toward the public dissemination of standard time. He considers it eminently proper that the department over which he presides should, as far as practicable, assist in a work in which the whole community is interested, and he offers the active cooperation of the Signal Service in every part of the United States, in the maintenance of accurate standard time, and giving it to the public by dropping time balls at all important stations.

Mr. Carpmael, Chief Director of the Meteorological Department of Canada, would similarly co-operate in every practicable way. There would, therefore, be no difficulty in giving effect to a scheme of introducing uniformity of time reckoning throughout North America, so soon as the railway and telegraph authorities and the general public express concurrence.

It is proposed—1. That the exact time should be determined astronomically at a central observatory; 2. That every town of any importance should have a public time signal station; 3. That arrangements be made for placing each station in electrical connection with the central observatory at a certain hour every day; 4. That each station be furnished with automatical apparatus for making the proper signal, either by dropping a time

ball or by firing a gun at the proper moment; 5. That all the public and railway clocks in each and every locality be controlled electrically from the public time signal station.

I think it may fairly be claimed that no peoples are more progressive or more ready to adopt any needed change or manifest improvement than those who live in North America. And as there is no country except Russia where a greater necessity is presented, or a better field offered for the introduction of a comprehensive system of uniformity in time reckoning, it is more than probable that in this country the change will first be made.

As there can be little doubt that other countries will in due time follow the example of America, it is desirable that we should inaugurate a system which will readily commend itself by its appropriateness and simplicity. One that will have the best prospect of being ultimately adopted throughout the world. If we admit the principle that in a question of this kind it is not expedient to limit our view to any City or State or Province, but to embrace in our system the whole of the continent, it seems to follow that we should take a still broader view, and endeavor to apply the principle to all countries. Steam and electricity are rapidly altering the conditions of life everywhere, they are girdling the globe and bringing all countries nearer together. We get our unit measure of time from the earth's revolutions, it is therefore common property, and nothing can be more cosmopolitan in its nature. It is perfectly obvious to my mind that a system of uniform time which would be good for this country should be equally good for all countries on the face of the globe.

These views have met with the ready acquiescence of all who have given them careful consideration, and the system recommended by the several scientific bodies, for adoption on this continent, commends itself as a scheme which all nations may, with advantage to themselves and to general interests, accept.

The American Metrological Society and the Canadian Institute have each passed resolutions substantially as follows:

Resolved, That uniformity of time throughout the United States and Canada is demanded by the progress of events, and that a general system by which time may be reckoned in a uniform and accurate manner by the people of all nations throughout the globe is of the highest importance.

Resolved, That a great service will be rendered to the world by directing the public mind to the subject, and by securing the general adoption of a well-conceived system of uniformity, and that the society is hereby authorized to cooperate with other bodies in recommending a comprehensive scheme based on the following propositions:

1. Twenty-four standard meridians (one every 15 degrees of longitude) to be established around the globe for reckoning sectional or local time.

2. One of the twenty-four standards to be selected as a time zero or initial meridian for reckoning cosmopolitan time.

3. The time zero to coincide with the prime meridian to be common to all nations for computing longitude.

4. The twenty-four standard meridians to be designated by names, or by letters of the alphabet, or by degrees of longitude, numbered from the prime meridian westerly.

5. The prime meridian or zero for time and longitude to pass near Behring's Strait, 180 degrees from Greenwich.

6. The division of the day into two halves of twelve hours each to be discouraged, and a single series numbered from I to XXIV, substituted. In the cosmopolitan day, or period of time between two successive passages of the sun over the prime meridian, the single division to be made absolute.

I may avail myself of this opportunity of mentioning that the scheme of cosmopolitan standard time is being brought before various European societies under distinguished auspices. His Excellency, the Governor General of Canada, has been good enough personally to evince a deep interest in the question, and has been pleased to send communications to France, Belgium, Prussia, Austria, Russia and Switzerland. The subject will be considered by the Association for the Reform and Codification of the Law of Nations, at their meeting in August next at Cologne, in Rhine-Prussia; and it will,

on that occasion, find warm advocates in Dr. Barnard, president of Columbia College, and Mr. David Dudley Field, of New York. The question will be brought under the consideration of the International Geographical Congress, at Venice, in September next, supported by such men as Mr. Otto Strove, director of the Imperial Observatory, St. Petersburg; General Hazen, of Washington, and others.

In bringing these propositions under the notice of the American Society of Civil Engineers, I do not feel justified, on an occasion like the present, to refer at length to the voluminous papers which have been written, and the arguments which have been advanced, in connection with this question. Necessarily I have been brief, and I respectfully suggest, in order further to save the time of the convention, that a committee be appointed to examine and report at a future meeting.

I feel it proper to add that as the great object is to determine and establish a system which will secure the greatest advantages to the community, it is of vast importance to have the proposition carefully digested by those whose opinions have value with the public. An expression from this body of educated, scientific and practical men, must carry with it great weight, and will exact respect in every quarter.

In the discussion upon Mr. Fleming's paper, Prof. Hilgard, of Washington, expressed himself as coinciding with the author, and further said:

"It was proposed to have twenty-four meridians at different places in the world, which would be just one hour apart. At every one of these meridians the time will be the true time of the place; half an hour east of it the time will be slow, and half an hour west of it the time would be fast. There would be some difficulty about the time between the meridians, but the system would possess undoubted advantages over the present complicated one. If the system were adopted on this continent, and other continents followed suit in adopting it, they would then have the first meridian, from which all other times would be regulated on this continent."

THE PROJECTED SIMPLON TUNNEL THROUGH THE ALPS.

By G. T. LOMMEL.

Abstracts of Institution of Civil Engineers.

In an elaborate paper presented to a recent meeting of the Swiss scientific Society at Brigue, the author, as engineer and director of the Simplon Company, propounds his views on the internal temperature likely to be encountered in driving the projected tunnel through the Simplon, and on the plans consequently to be recommended for carrying out this great work.

Temperature.—After noticing various earlier data with regard to the internal temperature of the earth's crust, the author turns to the temperature observations obtained in the Mont Cenis and St. Gothard tunnels, plotting them graphically in the latter instance in connection with the mountain profile along the line of the tunnel. The general principles bearing upon the outward emanation of heat from the earth's interior, and the inward penetration of cold from its surface, are noticed in relation to mountainous country; but it is thought premature to attempt the construction of any general formulæ, for which far more numerous observations are yet needed. The conclusions deduced by Dr. Stapff* from the St. Gothard tunnel, and applied by him to the Simplon, are warmly combated at considerable length. Longitudinal sections showing the similarity of the mountain profiles along the line of the tunnels are given by the author for St. Gothard and Mont Cenis; and from a comparison of these he infers that, for the middle of the St. Gothard tunnel at 5,600 feet depth below the mountain summit, the maximum temperature of rock in the advance heading,

* *Vide* Minutes of Proceedings Inst. C.E., vol. lxii., pp. 399-407.

which was found actually to be 30.8° C. or 86½° F., might have been conjectured nearly enough, without the aid of any formulæ, from the 29½° C. or 85° F. previously observed in the middle of the Mont Cenis tunnel for its depth of 5,300 feet below summit. Even supposing Dr. Stapff's inference were admitted, of 47° C. or 117° F. for the rock temperature at the middle of the Simplon tunnel, the author is satisfied that by abundant ventilation the air temperature at the working places might be maintained some 10° C. or 18 F. lower; inasmuch as in the Comstock* mines, Nevada, with a rock temperature of 130° F. or 54½° C., the air temperature in the workings is by that means kept down to an average of between 108° and 116° F. or 42° and 46½° C. High temperature he regards as of secondary moment, the freshness of the air being the most important consideration.

Route.—For tunneling through the Simplon at its base, the author gives a plan showing three alternative routes of his own, for tunnels of about 11½, 12¼, and 12⅓ miles length; also a tunnel of about 12½ miles proposed by Herr Stockalper, with another of nearly 13½ miles. Of his own three proposals, the shortest tunnel has its northern end within half a mile of Brigue, in the hillside near the mouth of the Saltine ravine; while the other two start within 2 miles further northeast, from the Rhone valley a little above Brigue. The southern ends of all three are about ½ mile from Iselle, in the valley of the river Diveria. The longer routes starting from the Rhone valley involve heavier outlay on the tunnels themselves, but lighter on the approaches to them; their summit level is also from 60 to 160 feet lower, thereby easing slightly the gradient on the southern approaches; moreover, the conditions affecting temperature are in their favor. With all the experience gained at Mont Cenis and St. Gothard, the author considers the Simplon tunnel will be executed under much better conditions, its northern mouth being near the railway terminus at Brigue, while up to its southern mouth temporary rails can be laid with locomotive gradients along the 11¼ miles of road from the railway terminus at Domo d'Ossola. The valleys at each end of the tunnel are easy of access, and are inhabited; and their climate is that of the plains. Very extensive air-compressing and ventilating machinery should be provided, of at least 2,000 HP. at each mouth; for this purpose ample water power is available at the northern end from the Rhone, and at the southern from the Diveria with its tributary the Cherasca.

Mode of Driving.—The author agrees in recommending the English method, adopted at Mont Cenis, of driving the advance heading along the floor level of the completed tunnel; in preference to the Belgian method, adopted at St. Gothard, of driving the heading along the roof of the tunnel. In the latter case the driving of the heading was followed by its enlargement to the full size of the arch forming the upper half of the tunnel; then along one side of the lower half a trench, called the *cunette du strosse*, was excavated down to the final floor level; and lastly the *strosse** itself, or ledge remaining along the other side, was got out. The serious practical disadvantages attending the roof heading are dwelt upon in detail; the floor level of the portion excavated is incessantly changing, as the successive stages of the work are pushed forwards, causing continual delays for shifting the rails, pipes, and culverts; the successive enlaregments in rear of the heading cannot be got out rapidly, or at any rate not economically; and as these enlargements have to be made below the level of the heading, it is almost impossible to multiply the number of the working places. On the contrary, as the author illustrates by comparative diagrams, the other method, with the advance heading driven centrally along the bottom of the tunnel, presents the advantages not only of more favorable conditions in regard both to temperature and to health, but also of facilitating the ready removal of the spoil; in very long tunnels the latter consideration, taken in connection with speed of driving, outweighs all others. The rails &c. originally laid are here kept in use throughout to the completion of the tunnel, without ever having to be

* The figures here given are quoted from Professor Church's paper in the Transactions of the American Institute of Mining Engineers, vol. vii., pp. 46-9. *Vide* also Minutes of Proceedings Inst. C.E., vol. lvii., pp. 393-6.

* This is simply the German word *strosse*, a step, bank, or ledge.

shifted; the excavation of the subsequent enlargement is above the level of the heading; and consequently any number of working places can be opened out, and kept going simultaneously, without impeding the continuous removal of the spoil.

For the Simplon tunnel the author accordingly recommends concentrating operations, during the first years of the work, upon driving the heading along the bottom of the tunnel from each end, and deferring its enlargement almost wholly until the two headings meet. As they advance, however, a preliminary enlargement to the full size of the finished tunnel should be opened out at about every 1,100 yards distance, for a length of 90 to 110 yards, which should be completed with its lining of masonry. Each of these enlargements would be executed during the time of driving the heading through the next stage of 1,100 yards; and thus there would never be more than a single working place in operation in rear of the heading forebreast. Hence, the inconveniences and delays involved in keeping a number of working places going during the driving of the heading would be done away with. The permanent culvert excavated below the floor of the heading would be pushed forwards at the same rate, keeping it always up to within 100 yards in rear of the forebreast. The preliminary enlargements successively completed would afford conveniences for shunting and for storing materials; and as soon as ever the two headings meet, each of these places would present two working faces for pushing on the final enlargement of the rest of the tunnel with the utmost convenience and despatch. On this plan, the haulage could be done throughout by compressed-air locomotives, running at 9 to 11 miles an hour in the tunnel, and aiding the ventilation by the fresh air they discharge; and horses, which, besides their power being so expensive, vitiate the air worse than four times as many men, and keep the roadway always trodden up and foul, are done away with altogether. The work of drilling the blasting holes should, in the author's opinion, be done entirely by mechanical means, avoiding any use of manual labor for this purpose.

Allowing six to seven years for the completion of the heading throughout its entire length, with a sectional area of about 100 square feet, the further excavation of the tunnel to its full section of about 380 square feet (exclusive of the heading) would then be pushed forwards simultaneously in each of the fifteen to twenty preliminary enlargements along the course of the heading. In every one of these places would be erected a pair of huge traveling stages, for which a design is sketched; each staging would serve alternately for miners and for masons, so that, after driving one face for some 30 yards length, the masonry lining would be built up along that length, while the drills were shifted to drive the other face. With thirty drills, 100 to 120 holes could be bored to a depth of $4\frac{1}{4}$ feet in the working face, in four shifts of half an hour each; and allowing four hours more for blasting and clearing, six hours would suffice for $4\frac{1}{4}$ feet in advance. Halving this rate, to be safely within the mark, there would be two blastings per twenty-four hours, giving an advance of $8\frac{1}{2}$ feet. Hence with about 1,000 yards length to be excavated between each of the preliminary enlargements, the whole length of the tunnel would be completed to its full section within a year (seven days per week) after the heading had been driven through, or say fifteen to eighteen months at the outside. For removing the collective spoil of 1,500 to 2,000 cubic yards of rock per day from the whole tunnel, the author estimates that a stock of fifteen locomotives and two hundred roomy wagons would be ample, allowing one-third to be idle.

The paper is supplemented by a somewhat detailed sketch of the general arrangements proposed for driving the heading; for excavating the preliminary enlargements: for completing the entire tunnel to its full section; and for conveying the workmen, materials and spoil.

In a letter on the heat in the tropics, to the editor of the *Times*, Mr. G. J. Symons gives the following as the highest point reached by the shade thermometer in the years 1874–80:

	Barbados. deg.	Mauritius. deg.	London. deg.	Bombay. deg.
Average for 7 years.....	84.9	87.3	87.4	93.9
Absolute highest....	86.0	88.8	92.6	96.3

THE GOLDSCHMID ANEROID.

A FORM of barometer made in Zurich, and known as the Goldschmid Aneroid, has of late been extensively employed in this country in railway reconnoisance, as well as in more extended topographical work.

The simplicity of its mechanism seems to promise some advantage over the forms heretofore in use.

One of the oldest forms of *box* barometer and the one to which the name *aneroid* is restricted by some writers, is represented in Fig. 1. A rectangular

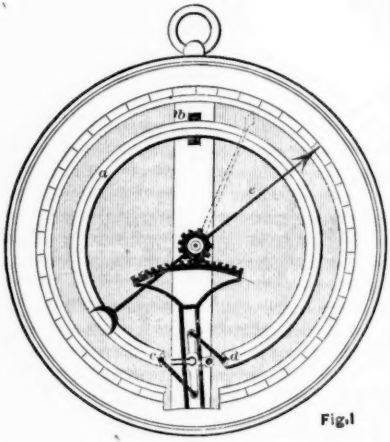


Fig.1

tube, from which the air has been perfectly exhausted, is sealed hermetrically, and having been bent into the form represented in the figure by *cbd*, is made fast at the middle point *b*. The varying pressure of the atmosphere causes the extremities *c* and *d* to approach or recede from each other. This motion is converted into a to-and-fro traverse of the index, by a mechanism sufficiently well exhibited by the diagram.

The form chiefly used at the present day, and sometimes designated as the Holosteric Barometer, is represented in Figs. 2 and 3. The vacuum box is in this case a short cylinder *h*, having an elastic top corrugated in concentric rings. A thin steel spring is made fast to the outer case at *l*, and, bending over, is attached to the vacuum box at its center.

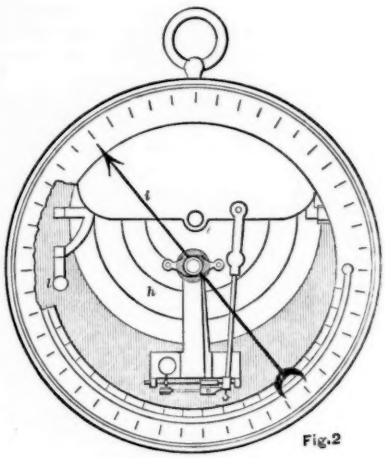


Fig.2

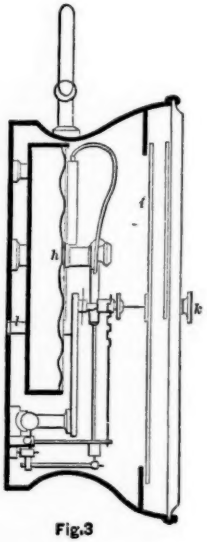


Fig.3

By the aid of an arm and the little rocker-shaft shown in the figure, the motions of the box are converted into the desired mo-

tions of the index, by means of a minute chain which winds about the center pin which carries the pointer. This chain is shown by a wavy line in both figures. A small hairspring supplies a slight counter pressure.

The graduation of these instruments is made to correspond with the height of the mercurial barometer, and is expressed as inches or millimeters.

The difficulties to be met by the maker, in securing accuracy of working, are those which arise chiefly from the varying elasticity of the several metallic elements under change of temperature. Greater simplicity of construction might be presumed to be attended with a smaller liability to a kind of error, for which it is exceedingly difficult to compensate. This is the theory of the Goldschmid Aneroid.

The instrument designed for ordinary engineering use is represented by Fig. 4.

Fig. 4

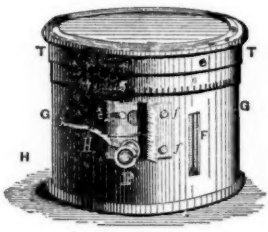


Fig. 5

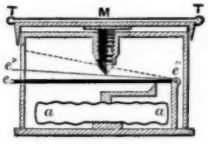
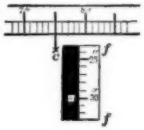


Fig. 6



The size recommended by the present makers for this service is $3\frac{1}{8}$ inches in diameter and $2\frac{1}{2}$ inches high.

The construction is exhibited by Fig. 5. The vacuum box, constructed as before described, is shown at *aa*. The motions of the box, caused by variations of atmospheric pressure, are conveyed directly to the lever, whose fulcrum is at e'', and whose free end is at e. This end, projecting through the side of the casing and working freely through a slot, is observed with a magnifying lens, and the reading on the index *ff* taken. But it is evident that the lever, working with proper ease on its fulcrum, must be supplied with a certain amount of counter-pressure. This is ingeniously done by aid of the delicate spring e', which is attached to the lever near the fulcrum. Bearing on the spring is the point of the micrometer screw M, whose head is graduated to hundredths and forms the top of the case. Both lever and spring are furnished at their extremities with bright metal heads, whose end surfaces lie in the same plane. The head e' is, under ordinary conditions, higher than e, as shown in Fig. 5. When a reading is to be taken the top of the case is turned until e' and e are side by side; the horizontal marks borne on the metallic heads being brought to an exact coincidence by aid of a lens (P in Fig. 1). The reading of the *inches* is taken from the scale *ff*, and of the hundredths from the divisions on the scale around the top of the box T; a fixed point c being marked on the cylinder. In figure 6 the indices exhibit a reading of 29.75 inches.

The thermometer F is an important part of the instrument.

In some of these instruments the scale *ff* bears no reference to the inches of the mercurial barometer, but is of an arbitrary character, and is different for different instruments. The value of the divisions is determined by comparison with standard instruments, and is carefully expressed in tabular form on the cover of the box.

Some corrections for temperature and pressure are required in the use of these instruments which, although desirable in the more common forms of aneroid, have not heretofore been considered necessary. In the latter instruments, however, when of the best construction, a *compensation* has been effected which renders a correction for temperature unnecessary. In the Goldschmid aneroids no compensation is attempted, but each instrument is furnished with a table of corrections which have been prepared from observation on standard instruments.

Thus, aneroid No. 3187, imported

last year, bears on the cover the following:

CORRECTION TABLE.

For Division.	*For Temperature.*
26.0″ = −0.02	28° to 48° = 0
26.5″ = −0.03	52° = +0.01
27.0″ = −0.03	56° = +0.015
27.5 = −0.02	60° = +0.025
28.0 = 0	64° = +0.035
28.5 = +0.03	68° = +0.04
29.0 = +0.06	72° = +0.05
29.5 = +0.10	76 = +0.07
30.0 = +0.14	80 = +0.09
30.5 = +0.19	84 = +0.11
31.0 = +0.25	88 = +0.13
	92° = +0.15

The temperatures are, of course, taken from the thermometer that forms a part of the instrument, and which, when the latter is carried slung from the sholder, may exhibit a temperature considerably higher than that of the air.

Two examples of altitudes taken with the instrument previously referred to (No. 3187) will serve to show the kind of correction necessary, and as both examples apply to the same mountain (Kiarsarge of Conway, N. H.,) they will together indicate the character of the instrument.

Ex. I.—July 9th, 1881.

Station.	Time.	Bar. Reading.	Temp. Air.	Temp. Inst.	Correct'ns Temp.	Correct'ns Press.	Corrected Reading.
Fryeb'g.	6.00A.M.	29.51	66°	66°	+.04	=.10	29.65
Mt. Kiar-sarge..	1.00P.M.	26.75	74°	74°	+.06	−.03	26.78

Ex. II.—August 9th, 1881.

Station.	Time.	Bar. Reading.	Temp. Air.	Temp. Inst.	Correct'ns Temp.	Correct'ns Press.	Corrected Readings.
Fryeb'g.	7.00A.M.	29.34	60°	65°	+.03	+.09	29.46
Mt. Kiar-sarge.	1.20P.M.	26.48	65°	75°	+.06	−.03	26.51

In both these examples another reading would have been taken at Fryeburg on the return, if the better alternative of securing hourly readings of a stationary barometer at Fryeburg had not been followed. On July 9th there was no change in the Fryeburg barometer. On August 9th the following readings were taken at Fryeburg:

7 A. M.	29.53	1 P. M.	29.46
8 "	29.52	2 "	29.455
10 "	29.515	3 "	29.40
12 "	29.46		

As this set of observations indicates a fall of .07 in the interval between the base and summit readings, it becomes necessary to make another correction to the last column.

Correcting the first reading to accord with the fall indicated by the stationary barometer, we get after all corrections:

Fryeburg, 29.39.
Mt. Kiarsarge, 26.51.

A convenient formula for estimating heights from barometric observations is

$$D = 60000\,(\log. B - \log. b)\left(1 + \frac{T + t - 60}{900}\right)$$

in which

D = difference in altitude in feet.
B = height of barometer in inches at lower station.
b = height of barometer in inches at upper station.

T and t are the temperatures of the air in Fahrenheit degrees.

Applying this formula to our first example we have:

$$D = 60000(1.47202 - 1.42781)\left(1 + \frac{140 - 60}{900}\right) = 2887 \text{ ft.}$$

The second example gives:

$$D = 60000(1.46820 - 1.42341)\left(1 + \frac{125 - 60}{900}\right) = 2881 \text{ ft.}$$

As the station at Freyburg is 434 feet above the sea, the estimated total height of Kiarsarge would be, in one case, 3321 feet, and in the other 3315 feet.

Prof. Airy's table gives 3319 and 3314 from the same data.

The instrument employed in the above measurements has been used in many other cases of altitudes from 3000 to 4000 feet. An error of about 2 per cent. in excess has been detected in those cases where the altitude has been measured by more accurate means. It seems likely that the special correction table needs some slight revision.

There is no doubt that all aneroids

need a careful comparison with standard instruments or a series of trials upon known altitudes, in order to determine the proper corrections. Such trials should be made at different temperatures and under different conditions as to rising or falling at the time of observation. The tables of corrections furnished by the maker cannot well be substituted for those made by a careful observer deduced from systematic work. The air pump, the hot chamber and the freezing box are convenient, but inadequate substitutes for a large number of trials under normal conditions.

With an aneroid, whose working is familiar to the engineer, there seems to be no reason why it should not be substituted for the level in all preliminary surveys. The field notes required would be the same as in the foregoing example with the *distances* in the place of the names there given. The calculations would be much simpler than is indicated by the formula applied in these cases.

For contiguous stations the following table from Symons' Pocket Altitude Tables may be conveniently employed:

Mean temperature...	30°	40°	50°	60°	70°	80°
Mean pressure, 27in.	9.7	9.9	10.1	10.3	10.6	10.8
" " 28in.	9.3	9.5	9.8	10.0	10.2	10.4
" " 29in.	9.0	9.2	9.4	9.6	9.8	10.0
" " 30in.	8.7	8.9	9.1	9.3	9.5	9.7

To find the difference in height between two stations: Find the mean pressure; also the mean temperature. The number in the table corresponding to these two means, if multiplied by the difference of the barometric pressures in hundredths of an inch, will give the difference in altitude very nearly.

The Goldschmid aneroid recommends itself by its construction, and although the errors are more numerous and larger than in the better class of *compensated* instruments of the *holosteric* pattern, it is reasonable to presume that they may be measured with greater certainty, and therefore more completely corrected.

A smaller and ruder instrument called the Pocket Aneroid is made by the Zurich manufacturers. It is only $1\frac{1}{2}$ inches in diameter and $1\frac{1}{4}$ inches high. A bar fastened to the top of the vacuum box takes the place of the lever in the larger instrument.

A larger size is also made in which the movements of the vacuum box are directly observed with a compound microscope.

Fig. 7

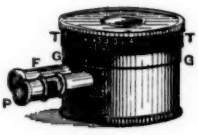
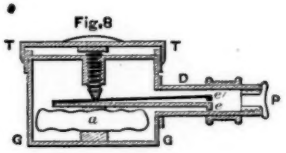


Fig. 8



WRITING in answer to a question on cleaning out lime-incrusted water pipes, a correspondent of the *American Manufacturer* writes: "As a sort of 'shop kink' I give you a curious experiment tried on an engine water supply pipe that had become choked up with lime incrustation. After hammering it for an hour or two and kindling a fire all over it, without any result, one end was plugged up, and about a pint of refined coal oil was poured in the other end—all it would hold—leaving it to stand all night. The next morning the entire mass slid out a solid lime core."

A VARIETY of coal, said to be the most highly-carbonized member of the coal series hitherto described, has been found near Schunga, on the western shores of Lake Onega. It contains about 91 per cent. carbon, 7 or 8 per cent. water, and 1 per cent. ash. This coal is extremely hard and dense, has an adamantine lustre, is a good conductor of electricity, and has a high specific heat—0.1922. Although containing as much carbon as the best graphites from Ceylon, it is not a true graphite, inasmuch as it is not oxidized by potassium chlorate and nitric acid, but behaves towards those re-agents like an amorphous coal.

THE ART OF FOUNDING IN BRASS, COPPER, AND BRONZE.*

By EDWARD TUCK.

From "The Architect."

THE origin of the art of founding can only be a matter of speculation, extending as it does so far back in the past history of the race, a history to a very large extent wrapped in obscurity and mystery. But the marvelous results of the various operations and the immense importance they have to mankind, have caused many in ancient times to assert that the art was communicated to man by the gods. Some, and with a larger share of truth, consider that man, finding by accident that certain minerals by the force of fire yielded a metal, repeated the experiment on other minerals, finding out other metals, and thus ultimately all the differing forms in which they exist in the earth. As late as 1762 a large mass of mixed metals, composed of copper, iron, tin, silver, was melted out of the earth during the conflagration of a wood accidentally set on fire, and various ancient historians speak of metals having been melted out of the earth during the burning of woods in the Alps and Pyrenees.

Copper is occasionally found in nature in a metallic state so pure as to be used for manufacturing purposes either for making articles of copper or alloys. There are examples of this in the mines of Lake Superior in North America, where large masses of copper have been found weighing several tons. It may, therefore, be considered quite possible that quantities of copper were found in the earth in the olden time, so that the ancients could possess the metal without the necessity of smelting. But, however, this fact must be stated, that where a mass of copper is found embedded in the earth at any depth it would require a greater amount of skill and mechanical knowledge to get this into working operations than to smelt the ore. Such a mass could not be broken up like stone, but must be cut, and therefore would require tools of particular hardness, and other mechanical appliances, to obtain which requires a greater and more refined knowledge of metallurgy than smelting copper from the ore.

But whatever or wherever may have been the origin of the art, it is quite certain that it originated at the very earliest period of man's history and has gone down with him along the stream of time to this age. It has had, as all arts have had in varying ages and nations, its rise and decline, which make the investigation of its history a somewhat difficult task. Still, by the aid of researches which have been made amongst the ruins and relics of past buried ages, we have been able to gather together some facts which help us to form something like a history of the art, very imperfect in many points, yet enabling us to form some idea of the methods of working and the means by which certain results which are matters of wonder to us even now were accomplished.

We have, it is true, in these modern days advanced far, very far, in the metallic arts; but in the great facts and principles we are no farther than the men of the past. In the matter of tools and means of production we have advanced so that we may produce in one week as much as they did in one year. But still the fact remains, *they accomplished the work*, and in the especial matter of bronze we have not yet reached the height of perfection to which certainly they attained.

Pliny and other ancient writers are very far from being correct in their descriptions of the manufacturing processes; and even the translators of their works have added to the confusion, either through ignorance, or on account of the poverty of the original language in technicalities, as we find brass in one place, white copper in another, copper in a third, all referred to indiscriminately, whether referring to pure copper or the

* A summary of the second prize essay of the Worshipful Company of Founders, 1880-81.

alloys whitened by the addition of lead, tin, or any other process; although Pliny certainly does describe more correctly the casting of bronze, for he says: "The mass of copper was brought to a liquid state, then was thrown into a third part of old bronze and 12½ per cent. of plumbum argentarum," *i.e.*, tin and lead in equal parts. We shall, therefore, trace the history of the art of founding, so far as we have been able to gather it from the past history of ancient times and the researches into and about the buried cities, and trace its course down through the ages to the present time.

The oldest reference we find in Holy Writ is in the Book of Job (the oldest work extant), Ch. xxviii. 2, "Brass is molten out of the stone." In the original Hebrew the word is *Nechosheth*, meaning literally copper. This must be so, as brass, being an alloy and not a pure metal, is not smelted, or, as it is put here, "molten out of the rock." The next reference is in Genesis iv. 22; "Tubal Cain, an instructor of every artificer in brass and iron." The same word, *Nechosheth*, is used here, literally copper; but seeing that copper is a difficult metal to work, we believe that the alloy of copper bronze is really meant. We incline to this belief because there is only one other reference to copper in the Old Testament (Ezra viii. 27): "Two vessels of fine copper, precious as gold." And here the same word is used. We find that tin, which mixed with copper forms bronze, certainly was known to the ancient Israelites, as in connection with the spoil taken from the people of Midian 1452 B.C. (Num. xxxi. 22) they are commanded by Moses to purify the silver, brass, iron, tin, and lead by passing it through the fire. (Moses appears here to mention all the metals then known.) Whether the tin came from India or not there is no sufficient evidence to prove, but it appears certain that the productions of that land were known in the earliest times, by "the gold of Ophir" being mentioned in Job.

If the Phœnician ships did not actually sail to India, its productions arrived partly by land through Arabia, partly through more distant marts established midway from India by the merchants of those and later times; and we have evidence of their having arrived in Egypt at the early period of Joseph's having been taken there, by the spices which the Ishmaelite caravans were carrying to that land. And the amethyst and other objects discovered at Thebes, of the time of the third Thothmes and succeeding Pharaohs, and which must have been brought to Egypt, argue very strongly that the intercourse was constantly kept up. Bronze, composed of tin and copper, was found in Egypt of the time of the sixth dynasty, 2,000 years B.C.

The first work of art of which we have any details in Holy Writ is the Ark made by Moses, and generally called "the Ark of the Covenant." It was also the first work performed by the Israelites as a nation. A large portion of the works in connection with this are of pure gold beaten out with the hammer; and although these show mechanical skill of a very high order, they are outside the scope of our paper.

We read (Exodus xxxviii. 8), "And he (Moses) made the laver of brass, and the foot of it of brass, of the looking-glasses of the women," &c. The word translated "foot" should be, as given in the margin, "cover." This laver, or large basin, in which the priests were to wash, must have been a large work to cast; and it shows a complete and accurate knowledge of the different sorts of bronze for different purposes that the cover should be made of the mirrors of the women, brought by them out of Egypt, and which, containing about one-third more of tin in the alloy, constituted speculum metal. So that the cover of this huge washing basin formed, when raised, a mirror in which the priests could examine themselves before approaching the altar. There were besides this many other articles used in the erection of "the Ark of the Covenant" made of bronze. Dean Prideau gives as the weight of bronze used 10,277 lbs. troy weight. The entire weight of the articles made in the three metals, gold, silver, and brass or bronze, was 14 tons 2 cwt. No one can read over the narrative of that undertaking, viewed independently of the adverse circumstances of the Israelites, wanderers in the wilderness, without perceiving that many amongst them possessed great skill; some had most probably been amongst the highest class artisans of Egypt. The ease with which

these elaborate works connected with the Ark, as well as the Golden Calf and the Brazen or Bronze Serpent, were produced, show that they had not been employed solely in the labor of brickmaking whilst in Egypt, but that in all probability many of them were working men in the Egyptian foundries and other public works in which metal articles were manufactured.

Bronze being a mixture of copper and tin in variable proportions, every variation produces a bronze of different quality, more or less suitable for different purposes. One quality will have great hardness and be very brittle—another hard and flexible; one gives a bright reflecting surface when polished, suitable for mirrors—another is famous for its sonorous quality, and is therefore suitable for bells, gongs, &c. Before these properties and differing qualities could have been found out some length of time must have intervened, as such knowledge of practical facts could not have been obtained until society had gained a considerable advancement in the arts. We are able to show by analysis that have been made of the bronze of the Egyptians and other ancient nations, that it was of such varied qualities, requiring a great amount of knowledge and practical skill as well as pure materials. Consequently these ancient people must have attained the knowledge before they could procure the varied articles. A chisel found by Wilkinson in an Egyptian quarry gave copper 94.0, tin 5.9, iron 1=100. A dagger, analyzed by Klaporth, copper 91.6, tin 7.5, lead 0.9=100. Bowl or dish from Nimroud, copper 89.57, tin 10.43=100. Bell analyzed by Dr. Percy, 84.70, tin 14.10. Thus showing where sound is required the amount of tin is increased, where strength is required the amount of tin is decreased. Dr. Percy found also a small casting, in the shape of the foreleg of a bull, forming the foot of a stand consisting of a ring of iron standing upon 3 feet of bronze. A section made disclosed a central piece of iron over which the bronze had been cast. The casting was sound and the contact perfect between the iron and the surrounding bronze, and it was quite evident on thorough inspection the bronze had been cast round the iron, and not the iron let into the bronze. The analysis gave copper 88.37, tin 11.33. No perfectly satisfactory conclusion can be arrived at whether the iron was employed because required in the construction or to economize the more costly metal—the bronze required for the ornamental purpose; we are inclined to the former in this case. Sir Henry Layard speaks of the bronze vessels, which he supposes to have been used in the religious ceremonies, as especially deserving of attention, as demonstrating the skill of the Assyrians in their treatment of bronze. One specimen may be particularly noted: "A thin hollow casting in bronze which was attached to the end of one of the arms of the throne. This casting had evidently been chased, and for that purpose must have been filled with some substance, such as pitch, which is used at the present time, as in the interior was some black compound which was like pitch and left an earthly residuum, and was probably a mixture of asphaltum and earth." It is quite evident that the Egyptians at the time the children of Israel were in captivity amongst them, and even long before that period, were very skillful in working the metals, especially bronze. We have no exact idea of the form of the furnaces or the materials used in their construction, but that they had great facility in constructing such furnaces is evident from the short time taken by Aaron to cast the calf or bull when in the wilderness. So we may presume that the Hebrews had been many of them laborers with the skilled artificers of Egypt, and, when leaving, had taken away their tools and the knowledge of the art in which they had worked with them. But whether the same or similar means were adopted for overcoming the difficulties of founding as in the present day, this fact remains, the difficulties were overcome, and the metals then known were used in abundance and as pure as we now have them. Wilkinson, in "Ancient Egypt," gives the figure of a smelting or melting operation from one of the ancient monuments. The furnace seems only a heap of fire on the surface of the earth, and the bellows are two large bags filled with air, upon which a man is standing with a foot on each bag, the aperture of the bag being connected with a pipe leading into the fire. While the man appears to be putting all his

weight on one bag to compress the air out into the fire, he is lifting up his other foot, and at the same time the upper fold of the other bag by a string in his hand, by which the bag is again being filled with air. This apparatus is no doubt both simple and rude, and if it refers to the ordinary metallurgical operations performed by the nation, one could hardly suppose that castings of any great size could be obtained except with much difficulty. Still it shows that the methods adopted for getting an intense heat were similar to ours, viz., by bellows or blowing.

Ordinary bellows are said to have been invented by Anacharsis the Scythian, but that must have been long subsequent to this period. Very little can be discovered to illustrate the means employed in metallurgical operations from the objects found in the excavated tombs, or from the paintings beyond the use of the blowpipe and the forceps, and the concentration of heat by raising cheeks of metal round three sides of the fire in which the crucibles were placed. Homer notices "that the Egyptians and other Asian workmen excel in the manufacture of arms, rich vases, and other objects inlaid and ornamented with metal." Herodotus and Helanius both say, "the Egyptians drank out of bronze goblets." We find that statues, musical instruments, implements of all kinds, adzes, axes and chisels, articles of funiture, bedsteads and footstools, and many other domestic utensils were all made of bronze. Also biers, on which the bodies were placed after death. The Egyptian vases are numerous and to be noticed for beauty of form and the design ornamenting them, as well as for the superior quality of the material. Those used in the service of the temples were especially beautiful. One found by Mr. Salt had an elastic spring to the cover, and the nicety with which it is fitted exhibits evidence of great skill in the workmanship.

The sistrum was, *par excellence*, the sacred musical instrument, and was usually of bronze or brass, sometimes inlaid with silver. One now in the British Museum is entirely of bronze, having a hollow handle closed by a movable cover of the same metal. The cymbals, or clappers, which when struck together emitted a sharp metallic sound, were of mixed metal, probably copper and silver, and in shape much resembling those of modern times.

It is not known at what times the ancient Egyptians began to cast statues and other objects in bronze, or how long the use of beaten copper preceded the art of casting. Many bronzes, however, have been found of a very early period. A cylinder with the name of Papi, of the sixth dynasty, has every appearance of being cast, and other bronze implements of the same age bear still stronger evidence of having come from a mould, all of which date more than 2,000 years before our era. The Egyptions, too, appear to have possessed the secret of giving to their cast bronze blades a certain degree of elasticity, as in the dagger now in the Berlin Museum, which probably depends for this property on the just proportions of the peculiar alloys used in its manufacture, as well as on its mode of having been hammered. Another remarkable feature in this bronze is the resistance it has offered to the effect of the atmosphere, continuing smooth and bright though buried for ages, and since exposed to the damp of the European climate. It may be said that the Egyptians had not any mines of tin wherewith to produce the bronze alloy. It is true that the mountainous districts of Egypt, between the Nile and the Red Sea, produced iron and copper only. Copper was also found in Arabia Petræa, which district was known to them, and even now amongst the heaps of refuse there we come upon the tubes used in the smelting apparatus. Mines are mentioned by Agartharchidas, a Greek writer of the age of Ptolemy Philometer, and he gives a curious picture of the mode of working these mines, which were probably near the coast now called Jebeel Allaka. For additional evidence we learn from Mak-rizi, an Arab writer, that this region produced silver and copper; and tradition names both Egyptian Pharaohs and Greek Ptolemies as workers of the mines. But, as we have already shown, they traded with India, and at this time, as well as from Spain, tin could be procured there.

The Phœnicians, to whom the art of navigation is so much indebted, and who carried the spirit of adventure beyond all the ancient nations, obtained tin from

both India and Spain long before they visited the more distant shores of Britain, and discovered how rich were the mines of that metal there. It was worth their while to undertake a long and risky journey at sea, with possibly no other method of ascertaining their course than the stars, from the high price they were able to obtain for this commodity in Egypt and other countries where, as at Sidon, the different branches of metallurgy were carried on to great perfection. Strabo, Diodorus, Pliny, and other writers mention certain islands discovered by the Phœnicians, which, from the quantity of tin they produced, they called Cassoterides, though the locality is not given, for Strabo says, "The secret of the discovery was carefully concealed;" and it is said that a Phœnician trader ran his vessel on a shoal and was shipwrecked, when pursued, rather than disclose his country's secret; for which he was rewarded from the public treasury. Strabo and Pliny both mention that tin was found in Gallicia and Lusitania, and further say that in consequence these countries became a rich mine of wealth to the Phœnicians.

Herodotus describes the doors of the Temple of Belus, at Babylon, as made of metal, probably bronze. The people would be more induced to attempt such work as bronze doors of their temples and public buildings in consequence of the scarcity of good timber suitable for the purpose in the land.

The next great work of ancient times, of which we have any details, is the making of the various bronze and brass articles used in the building and fittings of Solomon's Temple, at Jerusalem, 1011 B.C., and this gives a really good and complete idea of the progress made in the art at that period of time.

After the formation of the Ark and its various fittings, the Hebrews were not called upon again publicly to exercise their skill in metal work. The forty years of desert wanderings rendered such quite unnecessary; and as all those that came up out of Egypt died in the wilderness, in all probability with their death passed away much, if not all, the skill and ingenuity then shown, except for weapons of war and possibly implements of agriculture. They (the Hebrews) for some centuries were so much engaged in taking possession of the land they were to inhabit in wars and fightings, that the ordinary arts of civilized life were not and could not be cultivated; so that, notwithstanding the enormous wealth they had accumulated in the time of King David, yet when Solomon, his son, began to erect the Temple (which was a work their forefathers, when they left Egypt, could have accomplished without assistance) there were none among the people who could do the skilled work neccessary in casting and working the various metals. In consequence, Solomon has to negotiate with the King of Tyre to send him men and materials to do the work. "Send me, therefore, a man cunning to work in gold, in brass, and in iron," "and that can skill to grave with the cunning men with me whom David my father did provide" (referring to some skilled workmen whom the same king had sent to King David at an earlier period).

Singularly enough, the man sent by the King of Tyre as chief of the workmen was himself of Jewish descent on his mother's side, and had come of a family of metal workers, for we read, "his father was a man of Tyre, a worker in brass." This man directed the whole of this department of the work. The vastness of the quantity of bronze or brass used we are unable to determine, for we find (1 Kings vii. 47) "Solomon left all the vessels unweighed, for they were so many, neither was the weight of brass found out."

It is impossible for any one to read the graphic account given of the Temple construction in the Book of Kings, especially of the productions in metal, and not be amazed at the great variety of the work done, and the beauty and finish with which it must have been executed, as well as the great quantities and immense castings, which would require the highest mechanical skill and knowledge.

The two bronze pillars which were fixed up in the porch of the Temple must have been splendid specimens of workmanship. Taking the cubit at the generally-recognized measurement, 21 inches, the pillars, inclusive of the capitals, will have measured over 40 feet in height and 7 feet in diameter, and the weight of the metal would be from 23

tons to 28 tons. Another question arises in connection with these pillars: if they were hollow, as Whiston in his translation of "Josephus" considers they were, it follows that the use of cores must have been known and practised at this time, although this invention is ascribed to Theodorus and Rhæcus of Samos at a much latter period; but this may be only another instance of the knowledge of certain kinds of manufacture being lost and rediscovered at some later period.

In addition to these pillars, there was the Brazen or Bronze Altar, another gigantic work probably weighing about 200 tons; also the Molten Sea, an immense semicircular vessel measuring 17½ feet in diameter and 8¾ feet deep, and containing 16,000 to 20,000 gallons of water, supported on a pedestal of twelve bronze oxen. We get no idea from the account of the size of these castings, but they must have been of sufficient size and strength to support the vessel, which, when filled with water, would weigh probably 100 tons.

In addition to these large articles, there were a large number of smaller ones, equally good in construction and workmanship; but a full description of these must be left to a further article. It is apparent that different qualities of bronze were used, for some of the articles are stated "to be of bright brass," evidently different mixtures of the alloy for the differing purposes. It is clear from the vast size of the castings that good mechanical contrivances must have been used to remove, fit up, and place them in position.

These works were cast "in the Plain of Jordan in the clay ground," or, as should be more correctly rendered, "in the depth of the clay ground between Succoth and Zarthan," showing them to have been moulded in clay. Such large quantities of metal would require to be melted in a series of furnaces, in which the metal could be fused at one time, all tapped together, and the metal let run into the mould. A series of such furnaces would be constructed in a sort of a circle or square, under one large dome or roof, forming a chimney or tower.

It is most probable that such a method was adopted in those days, as we find from Nehemiah iii. 11: "Malchijah, the son of Harim, and Hashub, the son of Pahath-moab, repaired the other piece and the tower of the furnaces." This would refer to such a structure which, erected in the plain of Jordan for the temple works, may have continued a sort of national foundry up to the time the Jews were carried captive into Babylon. And again, the restoration and conseduent rebuilding of the Temple would require the same operations, and hence the repairing of the furnaces would be a necessary work.

The knowledge of the art of working in metals thus brought into Palestine by the Tyrians at the building of the Temple seems not to have afterwards declined, for we find frequent references in Scripture to works of this kind. In 740 B.C. King Ahaz, visiting King Tiglath-pileser at Damascus, saw an altar which pleased him, and sending Urijah, the priest, a drawing of it, one was made for him exactly similar. In 596 B.C. Nebuchadnezzar, King of Babylon, broke up the bronze pillars, the sea, and the bases of the Temple at Jerusalem, and removed the pieces to Babylon (a work of considerable difficulty) and it follows that probably many of the bronze articles found by Sir H. Layard and others in the ruins of that city may have been made from the bronze of the Temple furniture.

A singular confirmation of the idea that the brass and copper of Scripture are bronze is given by Mr. Edwards in the *Edinburgh Philosophical Magazine*, 1850, where he describes certain relics found near Marazion or Marghazin, one of the oldest towns in Cornwall, leading to the conclusion that the Jews had smelting houses near the shore. The remnants of these smelting pits are still called by tradition Jews' Houses, and the town itself is also called Market Jew, in addition to Marghazin, which means Market Mount; called so, no doubt by the Jews, as the place where the metals were purchased and sold. Possibly the bronze alloy, the mixture of copper and tin, may have been cast here in ingots, and shipped in that form; but this is conjecture.

The bronze of classical antiquity (Greek, *χαλκός*; Latin, *æs*) consisted of copper, with an alloy of one or more of the following metals—tin, lead, silver, zinc; the quantity and character of the alloy chang-

ing with the changing times or different purposes. Amongst existing bronzes, copper varies from 67 to 95 parts. The Phœnicians who traded with the Egyptians would also bring the tin alloy to the Greeks and Romans. Homer calls the metal Kassiteros, and this is equivalent to the Arab word Kasdeer, by which tin is known in the East; it is also called Kastira in Sanscrit. We are enabled from the analysis of coins to arrive at some results as to the admixture of the metals. It thus appears from their coins that the Greeks adhered to a mixture of copper and tin till 400 B.C., after which they used lead. Silver is rare in these coins.

The Romans used lead in their coins, but gradually reduced the quantity, till, under the Emperors Caligula, Nero, Vespasian and Domitian, they coined pure copper, but afterwards reverted to the mixture of lead.

This word χαλκός originally appears to have been the word for pure copper, and is so employed by Homer, who calls ερυθρος (red), αιθωψ (glittering), Φαεννος (shining), terms which will apply to pure copper or the bright alloys of bronze, such as the ancient mirrors were made of.

The old Greek poet describes the process of casting in almost similar terms to those in which it would be poetically described to-day, showing us that the processes then used and now were as nearly as possible alike, and proves the art of working the various substances to have been well understood at that remote period.

The passage referred to is in the "Iliad" of Homer, in the description of the manufacture of the shield of Achilles by the god Vulcan:

Thus having said, the Father of the Fires
To the black labor of his forge retires.
Soon as he bade them blow, the bellows turned
Their own mouths; and where the furnace burned
Resounding breathed; at once the blast expires,
And twenty forges catch at once the fires,
Just as the god directs; now loud, now low,
They raise a tempest or they gently blow.
In hissing flames huge silver bars are rolled,
And stubborn brass, and tin, and solid gold.

Thus the broad shield complete, the artist crowned
With his last hand, and poured the ocean round;
In living silver seemed the waves to roll;
And beat the buckler's verge and bound the whole.

In this description of the casting, Homer uses the word χαλκός, so that we can scarcely tell whether he means copper pure or alloyed. Further, it is more difficult when we read of the mythical Dactyles of Ida in Crete, or the Cyclops, being acquainted with the melting of χαλκός. It is not, however, likely, that the later Greek writers, who knew bronze in its real sense, would have used the word χαλκός without qualification to objects which they had seen, unless they meant it to be taken as bronze.

Pausanais speaks of an old statue he had seen made of separate pieces of metal fastened together with nails, and, using the same word, we understand him to mean bronze, as there exist very early figures of bronze thus made. We read also of the process called "sphyrelaton," being to hammer out the plates and fasten them together with nails. Pausanias also tells that "the Phœnicians pretended that Ulysses dedicated a statue of bronze to Neptune Hippius," but adds that "he does not give credit to the statement, as the art of fusing the metals and casting them in a mould was not then known." "In fact, the first who cast statues were Theodorus and Rhæcus, both natives of Samos."

It has been generally thought that their merit consisted in casting the statues with an inner core, which could be afterwards removed, leaving the castings light, and therefore less costly. But this is open to question, as we have before seen from Assyrian bronzes having been found cast with an inner core of a date older than Theodorus and Rhæcus, and there is now in the British Museum an early Etruscan statuette from Sissa, on the Volturno, with a core of iron.

The Samians were very early noted for their skill in this branch of art, and before the foundation of Cyrene, B.C. 630, they made a bronze vase ornamented with griffins, supported on three colossal figures of bronze, for the Temple of Juno.

The art was known at a very remote period in Italy. Among the Etruscans bronze statues were common before the foundation of Rome, 750 B.C., and Romulus is said to have placed a statue of him

self, crowned by Victory, in a four-horsed car of bronze, in the new city. Pliny states that "King Numa Pompilius, the immediate successor of Romulus, founded a fraternity of brass founders and bronze workers."

By the Romans a compound was used under the name of "oncalchum" or "auncalchum," which appears to have possessed the composition and properties of brass.

A brazen bull is traditionally said to have been contrived by Pericles at Athens for Phalaris, Tyrant of Agrigentum, 570 B.C. It had an opening in the side, to admit the victims, and a fire was kindled underneath to roast them to death. The throat was so contrived as to make the groans of the victims resemble the roaring of a bull. The artist was made the first experiment, and the tyrant for whom it was made was roasted in it, 549 B.C.

The oldest seat of bronze founding to any extent was the island of Delos, and next to that the island of Ægina. Between these two there existed a rivalry in the times of Myron and Polycletus, of whom the former used the bronze of Delos, the latter that of Ægina. More celebrated than either was the bronze of Corinth, about which it is said "that when Lucius Mummius burnt Corinth, 146 B. C., all the metals in the city melted during the conflagration, and, running together, formed the valuable composition called Corinthian brass. This is exceedingly doubtful, but there may be a spice of truth in it, as long before this period the Corinthian artists had obtained great credit for their method of combining copper with gold and silver. Pliny says of it: "It consisted of gold, silver and copper, and was considered more precious than silver, and little less valuable than gold." There were three kinds of it, varying in color from white to dark yellow.

Corinthian brass appears, for the most part, to have been used for the manufacture of drinking cups and ornamental utensils. The Syriac translation of the Bible says: "Hiram made the vessels for Solomon's Temple of Corinthian brass." Pumps were invented by Ctesibus, of Alexandria, 224 B. C., and were wholly or partially of cast brass or bronze. The most distinguished colossal statue of ancient times was the Colossus of Rhodes, one of the seven wonders of the world. In the days of its prosperity the capital of the island of Rhodes was adorned with over 3,000 statues, but this one exceeded them all. It was erected at the port of Rhodes, in honor of the sun, by Chares of Lindus, a disciple of Lysippus, 290 B. C., or 288 B. C., out of the spoils which Demetrius left behind him when he raised the siege of the city.

It is asserted to have spanned the entrance to the harbor of the island, and to have admitted the passage of vessels in full sail between its wide-spread legs. Its height was about 105 feet, the time taken for its construction was twelve years, and the cost amounted to 300 talents—about £70,000.

This stupendous work was thrown down by an earthquake about 224 B. C., and for nearly nine centuries lay in ruins on the ground. Pliny says: "It was a wonder to behold. Few persons could embrace the thumbs, and the fingers were longer than the bodies of most statues. Through the fractures were seen large cavities, into which large stones had been placed to balance it whilst standing." After the fall of the Roman Empire, when the island of Rhodes was conquered by the general-in-chief of the Caliph Othman, he sold the metal lying on the ground, weighing about 720,900 pounds, to a Jew, who loaded 980 camels in transporting it to Alexandria.

A statue of Zeus, executed at Tarentum 326 B. C. by Lysippus (the master of the maker of the Colossus of Rhodes), was 40 cubits high, and though it could be moved by a touch of the hand, yet resisted the force of storms by a support at the point of greatest stress.

On the number of bronze statues in these ancient times often depended the wealth of a State, cities such as Athens and Delphos having some thousands each.

Of the vast number made by the ancient sculptors nothing but a few fragments remain; but if the colossal head of Venus in the British Museum be taken as a typical example, it will show with what thinness and fineness the figures were cast. Or, again, as an instance of the quality of Greek bronze, the figure of Siris, also in the British Museum, on

which a plate of bronze will be seen beaten out till it reaches the thinness of note paper.

But if the larger works fail, there is an abundance of statuettes, candelabra, mirrors, cestæ and vessels of all kinds, Greek, Roman and Etruscan.

Works in relief (*νόρευμα*), whether beaten out, chased, or cast, are comparatively rare, though this branch of the art was practiced by the greatest sculptors. The Temple of Athene Chalkoites in Sparta had its walls covered with bronze reliefs, but this was an exception to the general rule adopted in the temple decoration.

The greater number of mirrors that exist are Etruscan; a few may be Roman and Greek. But the general rule of their being Etruscan reminds us of the reputation the Etruscans had for the production of works in bronze—not perhaps of high art, but what may be more correctly termed, "industrial art."

They were also celebrated for modeling in clay, and this, according to Pliny, "was the stage of art which immediately preceded casting in bronze, and went hand in hand with it."

The mirrors give the finest examples of patina which we find; in the alloy there seems to have been mixed a considerable quantity of silver in order to obtain a highly reflecting surface.

For articles of furniture the Romans employed Greek artists and workmen. In bronze were made the sellæ, square seats carried about at Roman entertainments; also footstools.

In the excavations made at Pompeii and Herculaneum various works in bronze are found, showing the general adaptation made of bronze by the Romans.

In the theater are bissellii, or chairs of state, made of bronze, and ornamented with silver, for persons of distinction and municipal authorities.

In the tepidarium of the baths are bronze benches, 6 feet by 1 foot, supported by four legs, terminating in the cloven hoofs of the cow, and ornamented at the upper end with heads of the same animal. In the same baths, a brazier of bronze, 7 feet 6 inches by 2 feet 6 inches, supported on cast bronze legs, representing winged sphinxes, terminating in lions' paws. In one of the shops a bronze urn, evidently used for making warm decoctions, and similar to the muller now in use; a bronze mould for making pastry, and a pair of scales—articles of these kinds in addition to the large number of statues and ornamental articles.

In all the bronzes from Pompeii and Herculaneum, the blue color of the patina is very brilliant, although in other bronzes it is more generally some shade of green. This arises from their lying so long in the earth, a difference of soil probably makes a different patina; but something is also due to varieties in the alloy.

Greek seats (*thronoi*) are sculptured on the Parthenon frieze; and sumptuous Greek furniture during the last two centuries B. C. was made of bronze, damascened with gold and silver. It does not appear that the process of gilding bronze was carried to any extent in classical times, except in the production of finger rings, of which a considerable number remain.

During the excavations made in the Palace of Tiberius at Capri, the bronze cock of a reservoir was discovered. As there were conduits of water, and pipes necessarily conveying it to the baths, the knowledge of cock making must have been known and practised, of which this discovery gives a practical proof.

By the time of the Byzantine Empire the power of modeling seems to have declined, and a taste for glittering appearance took its place, and hence the process of ornamenting bronze with reliefs was superseded by inlaying it with silver and other materials.

The art of bronze casting, which has thus sunk during the Byzantine period, was revived with great vigor in Germany in the eleventh century, and there used for the ornamentation of gates and doors of public buildings; notable instances being the bronze gates of the Cathedral of Hildesheim, A. D. 1015, and the column decorated with reliefs on the model of the Trajan Column at Rome, A. D. 1022.

In the twelfth century the art spread southward to Italy, and was at first taken up energetically in lower Italy. But though many interesting works of this date exist—and also from the thirteenth and fourteenth centuries—it was not un-

til the fifteenth century that the art obtained its full mastery. Then the revival of classical art became a real revival under the Florentine artists. Andrea Pisano had made a bronze gate in the Gothic style for the Baptistery of St. John at Florence, 1330 A. D., and in 1401 A. D., the Florentine Council decided to erect another. A competition of artists for the work resulted in the selection of Lorenzo Ghiberti. The contract was entered into with him and his father, November 23, 1403 A. D., and the gates completed and fixed April 24, 1424 A. D. They are truly a magnificent piece of art workmanship, remarkable in several respects as specimens of figure and ornamental modeling of the greatest possible excellence, and which have formed the models in this style for artists of all the following years, and of metal casting which cannot be surpassed.

The subjects of the twenty-eight panels of the gates are from the life of Christ.

On January 2, 1424 A. D., Ghiberti received the commission for the second pair of gates for the same building, and these, containing subjects from the Old Testament, were completed and fixed June 16, 1452 A. D. The Martinengo Tomb, in Brescia, erected about the year 1530 A. D. to Marcantonio Martinengo, though by what artist is unknown, is a fine specimen of this period. The basreliefs of bronze are subjects from profane history, and a triumphant procession in bronze adorns the principal frieze.

This development of taste extended to Naples, Rome, Milan, and Venice. Even Raphael designed ornaments for the moulders, of purest taste and most exquisite fancy.

In the sixteenth century it is found carried on with extraordinary skill in Germany at Nuremberg, Augsburg, Munich, and Coburg.

In France also we find the art gaining importance, as may be seen from the bas-reliefs in the Chateau d'Anet, the residence of Diana of Poictiers, which was restored under Philibert de Lorme, 1547–8 A.D., and the monument erected to the memory of Charles VIII., 1499 A.D., around which were figures of the Virtues, executed in gilt bronze. Since then the art of sculpture in bronze may be said to have reverted to nearly its original limits, namely, the production of statues and groups in the round.

In 1699 a bronze equestrian statue of Louis XIV. was erected in the Place Vendome, Paris. This was of gigantic size, containing 60,000 lbs. of bronze. It was demolished during one of the revolutions, 1792 A.D.

The wood furniture during the Renaissance period was decorated and inlaid with brass and bronze. In the eighteenth century we find Ciseleurs mentioned as makers of such brass edgings for furniture.

Perhaps the grandest bronze work of modern times is the colossal statue of Bavaria, completed and inaugurated at Munich, October 3, 1850. This statue was, at the suggestion of King Ludwig, designed by Schwanthaler, the sculptor, and his friend, Lazarini, who modeled the figure under his direction. For the casting it was necessary to melt 20 tons of bronze, a most perilous labor. To give some tangible idea of the size of the figure: In the head or upper part of the bust twenty-five men have found room, in the central part of the figure thirty-five to forty persons could dine, and the space of ground covered by the lower section is enormous in proportion. The figure of this colossal maiden, with the lion by her side, is 54 feet in height —nearly twice the height of the equestrian statue of Wellington, opposite Hyde Park corner.

THEORY OF THE INJECTOR.

By E. HERMANN.

From "Zeitschrift des Oest. Ingenieur-und-Architekten-Vereins," for Abstracts of the Institution of Civil Engineers.

THE author considered it desirable to re-examine the theory, although Zeuner has already given the undoubtedly accurate thermodynamic equation applicable to the case. The investigation of the dynamical conditions is wanting in Zeuner, and Grashof's equation gives results differing by 75 per cent. from those ob-

tained experimentally by Villiers. The units assumed are, kilogrammes, kilogrammes per square centimeter, meters, and square meters.

Let M_1=weight of feed-water; M= weight of steam; p_0=pressure in space from which steam is derived; p_1=pressure in steam nozzle; p_2 = pressure in condensation space; p_3 = pressure in space to be supplied (generally $p_3=p_0$; but, on account of the weight of the back-pressure valve, the greatest pressure in the delivery pipe is ξp_3, where $\xi=1.05$); p_4=pressure in space from which feed-water is derived. Generally $p_4=1.03$ kilogramme per square centimeter.

When steady motion is arrived at, the pressure in the section of the steam nozzle is p_1. Then two cases must be distinguished. If p_2, the pressure in the condensation space, is less than $0.577\,p_0$, then $p_1=0.577\,p_0$. More rarely p_2 is greater than $0.577\,p_0$, and then $p_1=p_2$. Hence it will be seen that the author proceeds on the assumption that immediately the pressure in the condensation space falls below $0.577\,p_0$, the steam enters it with the velocity due to $0.577\,p_0$ only. The theory is too complicated to be given. It leads to the general result that the ratio of the weight of the feed-water to that of the steam used is given by the equation:

$$\frac{M_1}{M}=\frac{\xi_1 w_1}{\sqrt{20\,g\,(\xi p_3-p_2)}}-1,$$

where ξ_1 is a co-efficient of correction, to allow for some small quantities neglected, and w_1 is the velocity of the steam in the nozzle. This has been ascertained in a previous investigation of the author, and is given by the equation:

$$w_1=\sqrt{\left\{\frac{2g}{J}\left(t_0+\frac{p_0 v_0}{C(b+t)}\right)-\left(t_1+\frac{p_1 v_1}{C(b+t_1)}\right)\right.}$$

t_0, p_0, v_0 being the temperature, pressure, and volume, of a kilogramme of steam in the boiler, and t, p, v, the corresponding quantities at the steam nozzle, C=0.1107, and b=187.2 for steam. The greatest suction height at which the injector will work is found to be:

$$h_{max}=\frac{p_1-p_2}{0.102}.$$

The theory is then compared with the experiments of Villiers, and the agreement is found to be satisfactory.

The author also gives practical rules for designing an injector for given conditions of pressure and discharge.

ON THE MAINTENANCE OF PURE AIR IN DWELLINGS.*

From "The Builder."

The question of how best to maintain pure air in a house has an important influence in domestic economy, because the health and the vigor of the inmates depend upon their living in a pure atmosphere.

The inhabitants of close rooms, persons who breathe air which has already been breathed, are subject to diseases which may cause death, amongst which may be mentioned pulmonary consumption and certain classes of fevers. But whilst some persons may be killed outright by breathing air which has been polluted by the breath of other persons, the majority are subject to a low condition of health. The reason of this is partly because the oxygen of the air is necessary for keeping in activity the chemical processes which are bound up with life, and that in the act of breathing, that is, in taking air into the lungs, the oxygen in the air is taken up by the lungs and the expelled air is thus deprived of its oxygen; and partly because an individual in expelling the air from his lungs in the act of breathing expels with the air carbonic acid gas, which in large quantities is fatal to life, as well as a large quantity of organic matter, *i. e.*, a portion of his body, which latter has a tendency to putrefy rapidly in stagnant air, and which may thus become a dangerous poison.

Those who live in a close atmosphere

*Paper by Captain Douglas Galton, C.B., F.R.S., ead at the Domestic Economy Congress, Royal Albert all.

have their vital energy impaired; they are less able to perform work. They more nearly approach to the condition of animals in a state of hybernation; they are less able to enjoy life. There is a case mentioned of a dressmaker who employed a large number of women in a very close room at a low rate of wages. Upon a remonstrance being made as to the condition of the atmosphere, ventilation and fresh air were supplied to the room. The women then complained that their wages were insufficient, because in consequence of the fresh air they were so much more hungry and required more to eat. That is to say, their vital energy was increased; and no doubt their capacity for work was much increased also. The same thing occurred when ventilation was introduced into soldiers' barrack rooms, through the efforts of Lord Herbert of Lea. The soldiers complained of the insufficiency of their rations, which had to be supplemented.

Mr. Leeds, a ventilating engineer of New York, mentions an experiment which he made with some flies illustrative of this. He confined a certain number of flies in a bottle full of breathed air and tightly sealed up. He also confined a certain number of flies in a bottle through which he allowed fresh air to circulate. The flies in the bottle filled with pure air were very lively, but they all died in twenty-four hours, as they had no food. The flies in the impure air became at once very stupid and could not fly about, but they lived ten times as long as those in the pure air. And thus we find that many poor people living in unventilated houses exist sometimes to quite an advanced age, but they are often sick and feeble. Therefore, when a person finds he cannot earn his living, or if he does earn it he is sure he cannot get sufficient food to eat, he had better imitate the hybernating animals as nearly as possible, and get into some close, unventilated place, and lie down in perfect quiet and repose, and not fret at all, and he will then be able to get along on very little food. But, if full employment is to be made of their faculties, persons must live in pure air.

Stagnant air can never be pure air. There are being given off perpetually into the atmosphere a number of deleterious substances—the emanations from the breath and other exhalations of every living creature—the emanations arising from the putrefaction of dead creatures or of decaying vegetable substances, the miasma from marshes, &c. These various poisonous emanations are being constantly changed into non-poisonous forms, or burnt up, as it were, by contact with the oxygen of the atmosphere, which is itself being continually renewed from other sources. The movement of the atmosphere facilitates this burning up of the poisonous emanations.

The atmosphere is always in movement. The Registrar-General gives the average movement of air as measured by an anemometer at Greenwich to be about 17 ft. in a second, or 12 miles an hour. It is rarely less than 6 ft. a second, or 6 miles an hour. Thus, if a single indvidual be assumed to occupy a space of 6 ft. high by 1 ft. 6 in. wide, situated in the open air, there would pass through this small space in an hour nearly 200,000 cubic feet of air, even when the movement of outer air is as low as four miles an hour.

In order to maintain purity of air in a house, it is necessary to keep up a continual movement of the air, supplemented by a continual change in the air. This movement and change of air must be maintained without causing a sensation of draught. The science by which this is effected is termed ventilation. It is a science of much simplicity in climates or in weather when the windows and doors can be kept perpetually open; but in this climate, especially in winter, the necessary condition of the avoidance of draughts makes it a very complicated matter, and renders it necessary in providing for a change of air to provide also for warming the inflowing air. The great differences of temperature which occur in this country, moreover, produce numerous other complications.

In considering the question of ventilation, the first question which arises is as to the quantity of fresh air which is required for change of air. If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from three to six times in every minute; but this would be a practical impossibility. And even if it were possible, it would entail condi-

tions very disagreeable to the occupants, who would have to live in a gale of wind. It is thus evident that in considering the condition of air indoors, we have to seek a standard of admissible impurity in the air, rather than a standard of purity of air comparable with what we have out of doors.

In judging of the amount of impurity which may be allowed in an inhabited air space, the sense of smell, when carefully educated, affords the best indicator of the relative purity and impurity of different kinds of air.

The volume of air which required to maintain the air of a room at a uniform standard varies with the character of emanations given out by the occupants of the room. For instance, the emanations given out by sick persons, and especially those from bad surgical cases, require for their dilution a greater volume of air than is requisite in the case of healthy persons.

Calculations have been made which show that, theoretically, about 3,000 cubic feet of fresh air per hour per individual should be afforded to preserve the air in a confined space at the required degree of freshness; but, in our climate, a careful practical examination of the condition of rooms in barracks and hospitals, judged of by the test of smell, shows that arrangements which appear to provide for a much less amount than that obtained by theoretical calculation, will keep the air of rooms occupied by healthy persons in a fair condition. These results have pointed to about 1,200 cubic feet of air per hour per individual.

This variation from theory seems to be partly due to the fact that there is always a change of air to a certain extent going on in a room. The walls and ceilings themselves allow of a considerable passage of air through them, which is proportioned to the difference between the temperature outside and inside a house, and varies with the materials of which it is constructed. Thus, ordinary bricks are nearly twice as pervious to air as sandstone, and plaster is much more pervious than brick.

If you look at the ceiling, you will see that an old ceiling is blackened where the plaster has nothing over it to check the passage of air, and that where the joists come, and the air has not passed so freely, it is less black. If you break the plaster, you will find that its blackness has arisen from its having acted like a filter, and retained the floating particles of dirt while the air passed through. Ill-fitting doors and windows allow of the passage of a considerable quantity of air.

A sleeping room is very warm at bed time; a rapid fall of temperature outside occurs, and at once a considerable movement of air takes place. The majority of occupiers of sleeping rooms in England close their windows at night; they often block up the chimney by a register or otherwise to prevent the blacks falling. They have no special inlet or outlet for changing the air. In the morning the room would, no doubt, be very close; but if it were not for the continual insensible change arising from the air passing through the walls, doors, and window chinks, &c., the occupants would be asphyxiated. A well-built house unprovided with special means for the inflow of fresh and outflow of vitiated air, is a real source of danger. For these reasons the form, position, and surroundings of a building are important, because the air thus insensibly coming in, as well as all other air admitted, should be taken from pure sources.

Rooms with a large amount of outside wall-space have a better chance of obtaining fresh air than rooms whose walls separate them from other occupied rooms; because the air, filtering in from an occupied room, would necessarily contain more impurities than fresh outside air. The inflow of air to a room takes place not only from all sides, but also from below. The air does not cease where the ground begins, but air permeates the ground, and occupies every space not filled by solid matter or by water. Thus, if you build on a dry, gravelly soil, where the interstices, between the stones are naturally somewhat large, you practically build over a large stratum of air. This air moves in and out of the soil in proportion to barometric pressure, and with reference to the wind.

The fact of this continual free passage of air in and out of the ground makes it important that the ground we live on should be free from impurities. We

might just as well (indeed, probably far better) live over a pig-stye than over a site in which refuse has buried, or in which sewer water has penetrated, or over a soil filled with decaying organic matter; because in cold or damp weather, when the air in the dwelling is warmer than the air outside, the upward movement of this warmer air will draw in air to supply its place from the ground on which the dwelling stands. This movement would be prevented if the whole surface under the dwelling were covered with an impervious material.

It has been the custom of many London builders to lease a site, to remove the valuable gravel and sand, and in order to fill up the hole thus caused, to invite people to deposit rubbish, often including foul garbage, on the site; and when the hole is thus filled up, to build a house over it. People are then astonished at fevers and sickness prevailing in new houses.

The size of a room does not permanently affect the purity of air in the room; that is to say, that the number of occupants in a large room being the same as the number in a small room, the same amount of air admitted and removed will eventually keep the two rooms in the same condition of impurity.

The degree of impurity in the air of an occupied room ultimately depends solely on these two things:

1. The rate at which emanations from the occupants are produced.

2. The rate at which the air of the room is being replaced by fresh air.

The advantage of large space is that the large room is longer in reaching the state of normal impurity than the small room. For instance, the following table shows the time required to bring air to a definite uniform standard of admissable impurity (viz., 0.2 per 1,000 of CO_2) in different sized rooms:

			H.	M.	S.
One man in	10,000	cubic feet.....	3	20	0
" "	5,000	"	1	40	0
" "	1,000	"	0	20	0
" "	600	"	0	12	0
" "	200	"	0	4	0
" "	50	"	0	1	0
" "	30	"	0	0	36

But besides this, the inflow and outflow of air necessary to maintain the standard of impurity is less perceptible in a large than in a small room; for the chief difficulty of keeping ventilation in action arises from the draughts it causes. Every one objects to a current of air which affects him, and desires that if a window is to be opened it shall be situated behind some one else. There is, moreover, in practice, this advantage in the larger rooms, viz., that the larger wall surface and the more numerous windows will allow of a larger insensible ventilation, and thus larger rooms will have an apparently less degree of impurity than small rooms. Although the uniform diffusion of carbonic acid is very rapid in the air of a room, the organic emanations given out do not in practice diffuse themselves either rapidly or uniformly. They hang about in corners where there are obstructions to the flow of air, or near the ceiling. On this account, some space between the occupants of a room is desirable. In sleeping rooms and in hospital wards, and, in fact, in all rooms where the height is above 10 ft. or 12 ft., the floor space becomes of more importance than cubic space. For adults in sleeping rooms it is undesirable to have a floor space for each of less than 50 superficial feet. And the floor space in dormitories in schools should certainly not be less for each boy or girl than a space of 50 superficial feet, or say 10 ft. by 5 ft. or 6 ft. 3 in. by 8 ft. In hospitals, from 90 to 120 superficial feet of floor space is generally afforded; and in fever hospitals, and in surgical wards, much more floor space is frequently desirable.

As before mentioned, the ventilation of a room means the removal of a portion of the air in the room, and the supply of a similar quantity of fresh air to take the place of the vitiated air thus removed.

This change of air may be effected in two ways: 1, by forcing fresh air into the room and allowing this fresh air to displace the air already in the room; or, 2, by drawing the air out of a room and allowing the fresh air to flow in to fill its place. In some cases a combination of both methods is adopted.

The extraction of the air is that which is simplest and most generally adopted. The extraction may be effected by fans or pumping machinery, but the usual system is to depend upon differences of temperature for determining the movement of air. The molecules of air are

but feebly attracted to each other, and increases of temperature or diminutions of pressure separate the particles from one another. Similarly, decreases of temperature bring the particles nearer together, and thus one cubic foot of warm expanded air weighs less than a cubic foot of cold air.

It follows that as warmed air expands it ascends, and as cooled air contracts it falls. It also follows that as the warmed air ascends the air around rushes in to fill its place. Everywhere this heating and cooling of the air is going on; the sun's rays, the proximity of a warm body, the vicinity of a cool shaded surface, all cause movements in the currents of air.

In a room, as air is warmed by the bodies of the occupants, it ascends; it comes against the glass of the windows, cools, and falls down. Draughts felt near the windows are not necessarily air coming in from the window, it may simply be the cooled air falling. It is on this law of the dilatation of air that all the movement of air depends, from the winds and hurricanes to the ventilation of our houses, except where we propel air by fans or other mechanical appliances.

The law which regulates this movement of the air in a confined space or a room, when the temperature is higher than that of the outside air, depends upon the following considerations:

1. Upon the difference of temperature of the air inside the confined space, as compared with that outside.

2. Upon the area of the aperture through which the air passes.

3. Upon the height of the column of ascending air.

Thus velocity of air in a chimney or flue depends on the height of the flue and temperature of the air as it ascends. Therefore, a fire lighted at the bottom of a flue produces a current upwards in the flue. The extraction of air by flues is the plan usually adopted.

The extraction of air by a properly constructed fan, worked by a steam engine, would be more economical than the flue extraction, especially when the warming of the air, which takes the place of that removed, is taken into account; but the strong recommendation of the chimney is its simplicity and its permanence. It requires comparatively little repair, and no skilled labor to look after it. The convenience of this system causes it to be almost universally adopted. The open fireplace is one example of it; the sun-burner is another example; but the system is also applied in every room in which there is an opening at the upper part, out of which the warm air can pass, and an opening below, through which fresh air can flow in. Thus, an ordinary sash window is an example. If the top sash is lowered and the bottom sash raised, the warmed air passes out of the room at the top, and the cooler outer air flows in below.

In the open country air is always in movement. In a town the buildings tend to prevent the rapid circulation of air; and, therefore, the smoke from the houses and the impure emanations from stables, from unclean street surfaces, and from ash pits, hang about and render the air impure.

In a house the space is so sub-divided that air is necessarily stagnant unless special arrangements are made to provide circulation. Of course, in the summer and in warm weather, it is comparatively easy to obtain circulation of air throughout a house, and to fill the house with pure air by opening windows and doors. But in winter and in cold weather or wet weather, when doors and windows are closed, it is necessary to provide special means for creating a circulation of air.

A change of air in a room means that the air in the room which is deteriorated by the breath of the occupants shall be replaced by fresh air. In cold weather it is necessary to provide in some manner for warming this fresh air, or else the temperature of the room would be so lowered as to be injurious.

In most London houses, the ventilation of the room in winter, and the warming of the air, depend on the open fireplace; and there is no better engine for the ventilation of a room. The way in which an ordinary open fireplace acts to create circulation of air in a room with closed doors and windows is as follows: The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the re-

mainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement towards the fire, flows upwards towards the ceiling near the chimney breast. It passes along the ceiling, and, as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace. A fireplace is thus powerful enough to draw into the room all the air it wants, and for this purpose will use indiscriminately all other openings, whether inlets or outlets, if necessary.

The rays from the fire pass through the air of the room without warming it; but they warm the surfaces, on which they impinge, of the walls and furniture, and thus communicate the heat to the air. Thus, in a room with an open fireplace, every object in the room contributes its heating surface to warm the air, which is drawn in cold from the outside by the fire.

But the cold air is liable to produce draughts. The only way to prevent draughts is to adopt means for providing fresh warmed air to supply the place of that removed. This may be effected in various ways. The fresh air may be brought to the back of the fireplace and there warmed by some of the spare heat which otherwise would pass up the chimney. By this means each room would be self-contained, so far as its heating and ventilation are concerned. Or, if preferred, a stove may be placed in the basement of a house, and fresh air brought to this stove to be warmed, and then conveyed by flues in the walls to the several rooms, and then admitted in convenient positions; or else the stove may be placed in the staircase or hall of a house, and fresh air be brought to it to be warmed, so that the staircase or hall shall form a reservoir of fresh air, from which the open fires in the several rooms draw supplies of air through the doors or through special openings.

Any of these arrangements will prevent draughts being felt in the rooms. Wherever an open fireplace is used, there should be some arrangement for the supply of fresh warmed air in winter to replace the air carried up the chimney; but as the fire itself warms the walls, and all the articles in the room, by its radiant heat, it is not desirable that this fresh air should be warmed to any great extent. Probably a temperature of 54° to 56° would be ample, as it would soon acquire in each room the supplemental heats which the occupants would desire. The lower the temperature of the fresh air, the larger would be the quantity of oxygen contained in a given bulk of air. Thus, a person breathes on an average when tranquil 16½ cubic feet of air per hour. A cubic foot of dry air at 32° contains 130.375 grains of oxygen, and with the air at 32° he would receive 2,164 grains of oxygen into his system. At 80° temperature, the air contains only 118.7 grains in a cubic foot, and in breathing 16½ cubic feet of air at 80° he would receive into his lungs only 1,971 grains of oxygen, or only about 90 per cent. of the oxygen which he would inhale at the temperature of 32°. Therefore the lower the temperature at which air can be supplied for breathing, consistent with comfort and the avoidance of draught, the better.

There is so great an advantage in the open fireplace as an engine of ventilation for rooms, that although many other and more economical means of heating our rooms have been suggested, it is questionable whether, on the ground of health, it would be wise to give it up.

One great evil from which we suffer in London is the smoke in the atmosphere, and this is aggravated by our open fireplaces, but not necessarily. The smoke is not only an evil in itself, but it aggravates the effect of the fogs which prevail, especially in this country. It seems that the tarry matter given out by the combustion of coal coats over the watery particles which float in the air in time of fog, and thus retards the evaporation, and causes the fogs in towns to be more continuous than they would otherwise be. The fog and smoke are a serious inconvenience to ventilation in London, because ventilation means the supply of pure air. The outside air in London is impure, and the only way to obtain comparatively pure air in the house is to pass the fresh air drawn in through cotton-wool filters. This entails a considerable amount of trouble, as the cotton-wool filter will, in foggy weather, have to be renewed every three or four days. But even on the finest days in London, when the air is what is called clear, it

will be found that the atmosphere is loaded with impurities. There is some smoke, much dust, of which the chief part arises from the enormous amount of horse manure spread over the streets, and many other impurities incidental to a thickly-peopled area. These impurities, and even the fog and smoke over a town such as London,do not rise to any very great height. The tops of the church towers, and of the loftiest houses, have been sometimes observed to be in a clear atmosphere on days when the streets are wrapped in fog. At the level of the tops of such lofty structures a much purer air may always be found than prevails near the street level, and this purer air could be brought down for the supply of houses. In all public buildings in London, especially in the Houses of Parliament, the supply of fresh air should invariably be from this purer source.

But this question should be looked at from a wider standpoint. The population of London, at the beginning of the century, did not exceed 960,000. It is now nearly 4,000,000. Thus a population not much smaller than that of Portugal, which is spread over 34,500 square miles, is concentrated in London on to 118 square miles. The houses spring up on the outskirts of London on every piece of spare land. Each house contributes to the smoke of London, and this smoke-contributing area, and the inhabited area which contributes impurities to the atmosphere, grow more rapidly than the arrangements made for removing the impurities, or for diminishing smoke.

We have had much legislation upon the subject of improving the purity of our rivers and water supply, but pure air is as important to us as pure water, and this question has been practically left untouched. There are Acts of Parliament prohibiting smoke, but, unfortunately, they have been left to be a dead letter, because of the private interests which they assail.

Those who live in the country find the pure air come to them on all sides, because of the constant movement which goes on in the atmosphere. Those who live in London must turn their attention to some method of diminishing the impurities with which London air is charged, or of putting in movement the atmosphere so charged with pollution. The first and most obvious step is to relieve the air from the enormous amount of smoke which is now daily thrown into it, and the next is to remove all refuse from the streets and houses as rapidly as possible. As a contribution towards the well being of the country, each householder should be bound to adopt some method of preventing smoke in his household.

The question of the avoidance of smoke is essentially one which comes under the cognizance of a Domestic Economy Congress, because smoke means waste; the consumption or prevention of smoke is the utilization of waste, because when smoke proceeds from a fire it shows that a large part of the fuel is going away into the atmosphere unconsumed. There have been many suggestions made to prevent smoke—the form of the fireplace, the use of anthracite coal, the use of gas instead of coal, or the use of gas in combination with coal.

One of the first persons who turned his attention to the prevention of smoke was Dr. Arnott. He proposed a fireplace which practically produced no smoke; but it had this inconvenience, that it gave a very dull fire. This inconvenience might, however, be easily remedied by a not very great alteration in the arrangements for admitting air to the top of the fuel.

It would be beyond the limits of this paper to enter upon the very large question of the various forms of grates, or of the other means for preventing smoke, and such a discussion would now be premature, as a committeé has been formed for the purpose of testing, in the course of the coming autumn, various new forms of fireplaces devised to prevent smoke.

There is scarcely any question at the present day more important to the inhabitants of London than that of devising means to purify the atmosphere. Parliament can make general laws prohibiting smoke, but the enforcement of the laws must rest with the local authorities. In London, unfortunately, the authorities whose duty it is to enforce the existing law have been very supine in the matter; and London suffers far more than ought to be permitted from the smoke of factories and large chimneys.

As regards the chimneys in private houses, although each gives out only a small quantity of smoke, the aggregate of smoke contributed by them is as serious an element in the pollution of London air as that from the factories. The source of pollution is beyond the reach of present legislation. It is a matter dependent upon the action of each individual householder. The most serious cause of air pollution in each house may be said to be the kitchen chimney, or the chimney of the hot-water apparatus. These must be in operation winter and summer. There are, however, numerous arrangements for cooking and for supplying hot water which do not give out smoke, and which are far more economical of fuel than the ordinary kitchen grate. The use of one or another of these arrangements would entirely abolish smoke from kitchen chimneys, and if kitchen chimneys and fuel used for cooking ceased to give out smoke, the atmosphere of London would be sensibly purer than it now is.

The other cause of impurity in London air—viz., that arising from dust—is more a matter for the local authorities than for the individual householder. The streets should be washed every morning, and swept more than once a day; the dust carts should be covered: dust from dust holes should not be brought up in open baskets and emptied, as it now is, into the open carts, so as to scatter the largest possible amount into the atmosphere, and in the face of the persons passing by; but dust should be daily collected from every house, and received in closed receptacles, to prevent any of it being spread in the atmosphere.

If the local authorities would set themselves seriously to work to prevent the pollution of London air in this direction, and if every individual householder would take the trouble to adopt some method of diminishing the smoke from his own house, a sensible effect would soon be produced on the cleanliness of London and on the purity of its atmosphere.

GAS FOR LIGHT AND HEATING.

By Dr. C. W. SIEMENS, F.R.S.

From the "Journal of the Society of Arts."

When, within the memory of living men, the gas burner took the place of the oil lamp, the improvement was so great that the ultimate condition of perfection appeared to have been reached. It is only in recent years that much attention has been bestowed upon the utilization of by-products with a view of cheapening cost, and that the consumer has become alive to the importance of having a gas of high illuminating power, free from nauseous constituents, such as bisulphide of carbon, thus providing a stimulant for progress on the part of the gas-works manager. This condition of things has been rudely shaken by the introduction of the electric light, which, owing to its greater brilliancy and cheapness, threatens to do for gas what gas did for oil half a century before. The lighting of the City of London and of public halls and works furnishes proof that the electric light is not an imaginary, but a real competitor with gas as an illuminant; and it is indeed time for gas engineers and managers to look seriously to their position with regard to this new rival. For my own part (Dr. Siemens said), I present myself before you both as a rival and a friend—as a rival, because I am one of the promoters of electric illumination; and as a friend, because I have advocated the use of gas for heating purposes during the last 20 years, and am not disposed to relinquish my advocacy of gas both as an illuminating and as a heating agent. Speaking as a gas engineer, I should be disposed to regard the electric light as an incentive to fresh exertion, confidently anticipating achievements by the use of gas which would probably have been long postponed under the continued *regime* of a monopoly. Already we observe, thanks chiefly to Mr. Sugg, both in our thoroughfares and in our apartments, gas burners producing a brighter light than was to be seen previously; and although gas will have

to yield to the electric light the illumination of our lighthouses, halls and great thoroughfares, it will be in a position, I believe, to hold its own as a domestic illuminant, owing to its convenience of usage, and to the facility with which it can be subdivided and regulated. The loss which it is likely to sustain in large applications as an illuminant would be more than compensated by its use as a heating agent, to which the attention of both the producer and the consumer has latterly been largely directed. Having, in the development of the regenerative gas furnace, had opportunities of recognizing the many advantages of gaseous over solid fuel, I ventured, as early as 1863, to propose to the Town Council of Birmingham the establishment of works for the distribution of heating gas throughout the town; and it has occurred to me to take this opportunity (when the gas managers of Great Britain hold their annual meeting at the very place of my early proposal) to lay before them the idea that then guided me, and to suggest a plan of operation for its realization which, at the present day, will not, I hope, be regarded by them as Uptopian. The proposal of 1863 consisted in the establishment of separate mains for the distribution of heating gas to be produced in vertical retorts, that might be shortly described as Appold's coke ovens, heated by means of "producer" gas and "regenerators." The Corporation applied for an Act of Parliament, but did not succeed in obtaining it, owing to the opposition of the gas companies, who pledged themselves to carry out such an undertaking, if found feasible by them. I am ready to admit that at the time the success of the undertaking would have involved considerable difficulties; but I feel confident that the modified plan which it is my present object to bring before you would reduce these difficulties to a minimum, and would open out a new field for the enterprise of those interested in gas works. The gas retort would be the same as at present, and the only change I would advocate in the benches is the use of the regenerative gas furnace. This was first successfully introduced by me at the Paris Gas Works in 1863, and has since found favor with the managers of gas works abroad, and in this country. The advantages that have been proved in favor of this mode of heating are—economy of fuel; greater durability of retorts, owing to the more perfect distribution of heat; the introduction of an additional retort in each bed, in the position previously occupied by the fire grate; and, above all, a more rapid distillation of the coal, resulting in changes of four hours each, whereas six hours are necessary under the ordinary mode of firing. The additional suggestion I have now to make, consists in providing over each bench of retorts two collecting pipes, the one being set aside for illuminating and the other for a separate service of heating gas. I shall be able to prove to you, from unimpeachable evidence, that the gas coming from a retort varies very greatly in its character during progressive periods of the charge; that during the first quarter of an hour after closing the retort the gas given off consists principally of marsh gas and other gases and vapors, which are of little or no use for illuminating purposes; from the end of the first quarter of an hour, for a period of two hours, rich hydro-carbons, such as acetylene and olefiant gas are given off; whereas the gases passing away after this consist for the most part again of marsh gas, possessing low illuminating power. According to the figures given in the experiment of M. Ellissen, President of the French Society of Gas Engineers, it appears that nearly two-thirds of the total production of gas takes place in the above period, while the remaining third is distilled during the first quarter of an hour and the last hour and three-quarters. It hence follows that by changing the direction of the flow of gas at the periods indicated, allowing the first results of distillation to flow into the heating gas main, then for two consecutive hours into the illuminating gas main, and for the remainder of the period again into the heating-gas main, one-third volume of heating and two-thirds of illuminating gas would be obtained, with this important difference, that the illuminating gas would be of 16.16 instead of 13.5 candle power, and that the heating gas, although possessed of an illuminating power of only 11.05 candles, would be preferable to the mixed gas for heating purposes in being less liable in its combustion to deposit soot

upon heat-absorbing surfaces, and in giving, weight for weight, a calorific power superior to olefiant gas. The working out of this plan would involve the mechanical operation of changing the direction of the gas coming from each bench of retorts at the proper periods of the charge. In order to distribute the two gases a double set of gas mains would certainly be required, but these exist already in the principal thoroughfares of many of our great towns, and it would not, I think, be difficult to utilize them for the separate supply of illuminating and heating gas, the latter being only taken into the houses and establishments where it is asked for by the occupiers. The public could well afford to pay an increased price for a gas of greatly increased illuminating power, and the increase of revenue thus produced would enable gas companies to supply heating gas at a proportionately reduced rate. The question may be asked whether a demand would be likely to arise for heating gas similar in amount to that for illuminating gas; and I am of opinion that, although the present amount of gas supplied for illuminating purposes exceeds that for heating, the diminution in price for the latter would very soon indeed reverse these proportions. Already gas is used in rapidly increasing quantities for kitcheners, for the working of gas engines, and for fire grates. As regards the latter application, I may here mention that an arrangement for using gas and coke jointly in an open fireplace combined with a simple contrivance for effecting the combustion of the gas by heated air, has found favor with many of the leading grate builders and with the public. As regards the use of illuminating gas, I have one more suggestion to make, which I feel confident will be viewed by you with interest. The illuminating effect produced in a gas flame depends partly upon the amount of carbon developed in the solid condition in the body of the flame, and partly upon the temperature to which these particles are heated in the act of combustion. Having shown how by separation a gas of greater luminosity may be supplied, it remains to be seen how the temperature of combustion may be raised. This may be effected by certain mechanical arrangements, whereby a portion of the waste heat produced by the flame itself is rendered available to heat the gas and air sustaining the combustion of the flame—say to 600° Fahrenheit, or even beyond this point. The arrangement I have adopted for this purpose is a burner of the ordinary Argand type, mounted in a small cylindrical chamber of sheet copper, connected with a vertical rod of copper, projecting upwards through the center of the burner, and terminating in a cup-like extension at a point about four inches above the gas orifices, or on a level with the top of the flame. A small mass of fire-clay fills the cup, projecting upwards from it in a rounded and pointed form. The copper vessel surrounding the burner is contracted at its upper extremity with a view of directing a current of air against the gas jets on the burner, and on its circumference it is perforated for the admission of atmospheric air. The bottom surface is formed of a perforated disc covered with wire gauze, and wire gauze also surrounds the circumference of the perforated cylinder. The external air is heated in passing through these "regenerative" surfaces, and the flame is thus fed with air, heated to the point above indicated, which, by more elaborate arrangements, might be raised to a still higher degree. The ball of fire clay in the center of the burner, which is heated to redness, serves the useful purpose of completing the combustion of the gas, and thus diminishes the liability to blackening of the ceiling. The arrangement for transferring the heat from the tip of the flame to the air supporting its combustion was applicable also to an open bat's-wing burner, but I have not yet had time to ascertain accurately the amount of increase of luminosity that may be realized with this class of burner. From a purely theoretical point of view, it can be shown that of the caloric energy developed in the combustion of gas a proportion (probably not exceeding 1 per cent.) is really utilized in the production of luminous rays; and that even in the electric light nine-tenths of the energy set up in the arc is dispersed in the form of heat, and one-tenth only is utilized in the form of luminous rays. It would lead us too far here to go into the particulars of these calculations, but it is important to call attention to them in order to show the large margin still before us

for practical improvements. I may here mention that another solution of the problem of heating the incoming air by the waste heat of the products of combustion has lately been brought under public notice by my brother, Frederick Siemens, which differs essentially from the plan I have suggested, inasmuch as he draws the flame downwards through heating apparatus, and thence into a chimney. In practice both these methods of intensifying a gas flame will probably find independent application, according to circumstances. By the combined employment of the process for separating the illumination from the heated gas, with the arrangement for intensifying the luminosity of the gas flame, the total luminous effect produced by a given consumption of coal gas may, according to the figures given, be increased threefold, thus showing that the deleterious effects now appertaining to gas illumination are not inseparable from its use. My principal object in preparing this communication has been to call your attention generally to the important question of an improved gas illumination, and more particularly to the subject of a separate supply for heating gas, which, if carried into effect, would lead, I am convinced, to beneficial results, the importance of which, both to gas companies and to the public, it would be difficult to over-estimate.

ON THE PROGRESS AND DEVELOPMENT OF THE MARINE ENGINE.*

From "The Engineer."

The author began by referring to a paper read at the Liverpool meeting in 1872, by Mr. F. J. Bramwell, F.R.S., on "The Progress Effected in Economy of Fuel in Steam Navigation, considered in Relation to Compound Cylinder Engines, and High-pressure Steam;" then proceeded to continue the subject from the date of that meeting, to trace out whether any, and if so what, progress had been made; further, to consider whether or no we have reached the finality so strongly deprecated by Sir Frederick Bramwell in the discussion referred to, and if not, then in what direction we are to look for further development.

From a table it would seem that the steam pressures are now much higher, the boilers have less heating surface, and the cylinders are much smaller for the indicated horse-power developed, than in 1872; and at the same time the average consumption of fuel is reduced from 2.11 lbs. to 1.828 lbs., or by 13.38 per cent. The author then briefly described the modern marine engine and boiler. The three great types of compound engines may be placed as follows in the order of their general acceptance by the shipowning community: (1) The two-cylinder intermediate-receiver compound engine, having cranks at right angles. (2) The Woolf engine in the tandem form, having generally the high-pressure and low-pressure cylinders in line with each other, but occasionally alongside, and always communicating their power to one crank. Such a pair of engines is used sometimes singly, oftener two pairs together, working side by side to cranks at right angles; recently three pairs together, working to cranks placed 120 deg. apart. The system affords the opportunity of adding yet more engines to the same propeller to an indefinite extent. (3) The three-cylinder intermediate-receiver compound engine, with one high and two low-pressure cylinders, the steam passing from the high-pressure cylinder into the receiver, and thence into the two low-pressure cylinders respectively. The cranks are placed at equal angles apart round the crank shaft, so as to balance the forces exerted upon the shaft. These three types may be said to embrace all the engines now being manufactured in this country for the propulsion of steam vessels by the screw propeller. In their leading principles they also embrace nearly all paddle engines now being built, whether the cylinders be oscillating, fixed vertically, or inclined to the shaft. The compound engine in fact, in one of these three

* A paper read before the Institution of Mechanical Engineers, by Mr. F. C. Marshall.

forms, may now be said to be universally adopted in this country; and the question of the relative value of simple expansion in one cylinder, and of compound expansion in two or more cylinders, which agitated the minds of some of our leading engineers ten years ago, is now practically solved in favor of the latter. The marine boiler of to-day is in all its main features the same as it was ten years ago. The single-ended boiler, made with two, three, and sometimes four furnaces, is the simplest form, and for all powers under 500-indicated horse-power is the most generally adopted. The double-ended form is largely used. It has been found more economically efficient than the single-ended form, by as much as 10 per cent. in the writer's own experience. It is generally adopted for engines of large power, but for small power is inconvenient, owing to its occupying more room lengthwise in the vessel, and also involving two stokeholds and therefore more supervision. At one time great difficulty was found in keeping the bottoms of boilers of this kind tight. Owing to their length, the unequal expansion due to different temperatures at the top and bottom caused severe racking strains on the bottom seams and riveting—so severe in some cases as to rend the plating for a large part of the bottom circumference of the shell. This difficulty has now been to a large extent got over, in consequence of the greater attention given to the form and direction of the water spaces in the boiler itself, so as to induce circulation of water; the introduction of the feed-water at the top instead of near the bottom; the more careful management now usual on the part of engineers; and lastly, the use of larger plates, welded horizontal seams, drilled rivet holes, and more perfect workmanship throughout. A modification of double-ended boiler is that introduced by Mr. Alfred Holt. It has many decided advantages, but is costly to make. The formation of the two ends into separate fire-boxes leaves the bottom of the boiler free to adapt itself to the variations of temperature to which it is exposed. The separation of the furnaces from the combustion chamber, excepting through the opening afforded by a connecting tube, is an advantage in the same direction, and avoids almost entirely the racking strains due to irregular furnace action. The weight of water carried is less, and that of the boiler may also be made less; while the elliptical form of the two ends gives greater steam space. A type of boiler largely used in her Majesty's Navy, somewhat like a locomotive boiler, is highly efficient in regard to weight and power developed. Many examples have yielded one indicated horse-power in the cylinders for every three square feet of heating surface, under natural draught and with a very moderate height of funnel; and this with a consumption of fuel not exceeding $2\frac{1}{2}$ lbs. per indicated horse-power per hour under a working pressure of 60 lbs. With the aid of a steam jet in the funnel, the heating surface per indicated horse-power has fallen below $2\frac{1}{2}$ square feet. The large water surface afforded for escape of steam secures almost entire freedom from priming, without the incumbrance of steam domes; and the large combustion chamber allows of the thorough combustion of the gases before their passage through the tubes. The locomotive type of boiler has lately occupied the writer's attention, with a view to its more definite introduction into marine work. The difficulties however which lie in the way of applying it to steamers going long voyages are very great. The principal difficulty lies in the necessity of burning a large quantity of fuel in a very limited space and time. This can only be done either by direct pressure or exhaust action applied at the furnace. In other words, we must either exhaust the funnel, which will absorb a large amount of power, but would be comparatively easy of application; or our stokers, as is the case with our miners, must work under a pressure of air. The writer stated that his experience in the manufacture and working of steel boilers was satisfactory. Many steel boilers of sizes varying from 6 feet diameter to 14 feet 6 inches diameter have left the works at St. Peter's since 1877, when the first was made; and in no case has there been a failure of a plate after being put into a boiler, either in the process of manufacture or in working at sea. The mode of working is as follows: For shell plates, from $\frac{5}{8}$ in. to $\frac{7}{8}$ in. thick, to warm each to a dark red heat before rolling, having previously

drilled a few holes to template for bolting the strakes together; the longitudinal seams are usually lap joints, treble riveted, requiring the corners to be thinned, which is done after rolling. The furnace plates are generally welded two plates in length, and flanged to form Adamson rings, and at the back end to meet the tube plate; the back flame box plates are flanged, also the tube plates and front and back plates, and wherever work is put on to the plate it is annealed before going into the place. The rivet holes are drilled throughout. In the putting together the longitudinal seams of the thicker plates of the shells, great care is always taken to set the upper and under plates for the lap to their proper angle before they are bolted together, a point generally overlooked by the practical boilersmith. The question of corrosion is one which is gradually being answered as time goes on; and so far very satisfactorily for steel. Some steel boilers were examined a few weeks ago which were amongst the first made; and the superintending engineer reports, "There is no sign of pitting or corrosion in any part of the boiler; the boilers are washed out very carefully every voyage, and very carefully examined, and I cannot trace anything either leaking or eating away. No zinc is used, only care in washing out, drying out, and managing the water." This is the evidence of an engineer with a large number of vessels in his charge. On the other hand, some of our most prominent Liverpool engineers always use zinc, and take care to apply it most strictly. The evidence of one of them is as follows: "We always fix slabs of zinc to most boilers, exposing not less than a surface of one square foot for every twenty indicated horse-power, and distributed throughout the boiler. This zinc we find to be in a state of oxide and crumbling away in about three months. We then renew the whole, and find this will last twelve months or more, when it is renewed again. Meanwhile we have no pitting and no corrosion; but, on the contrary, the interior surfaces appear to have taken a coating of oxide of zinc all over, and we have no trouble with them." Then the writer considered our present marine engine as to its efficiency and capability of further improvement. The weight of machinery, water and fuel carried for propelling ships has not had due attention in the general practice of engineers. By the best shipping authorities the writer is assured that every ton of dead weight capacity is worth on an average £10 per annum as earning freight. Assuming, therefore, the weight of the machinery and water of any ordinary vessel to be 300 tons, and that, by careful design and judicious use of materials, the engineer can reduce it by 100 tons, without increasing the cost of working, he makes the vessel worth £1,000 per annum more to her owners. That there is much room for improvement in this direction is shown by the following statement, giving, for various classes of ships, the average weight of machinery, including engines, boilers, water, and all fittings ready for sea, in pounds, per indicated horse power;

	lb. per I. H. P
Merchant steamers	480
Royal Navy	300
Engines especially designed for light draught vessels	280
Royal Navy, Polyphemus class, (given by Mr. Wright)	180
Modern locomotive	140
Torpedo vessels	60
Ordinary marine boilers, including water	196
Locomotive boilers, including water	60

The ordinary marine boiler, encumbered as it is by the regulations of the Board of Trade and of Lloyd's Committee, does not admit of much reduction in the weight of material or of water carried when working. The introduction of steel has reduced the weight by about one-tenth; but it will be the alteration of form to the locomotive, tubulous, or some other type, combined with some method of forced draught, to which we must look for such reductions in weight of material and water as will be of any great commercial value. The engine may be reduced in weight by reducing its size, and this can only be done by increasing the number of revolutions per minute. It has hitherto been the practice to treat the propeller as dependent upon the size of engines, draught of water, and speed required. This process should be reversed. The propeller's diameter depends on the column of water behind, necessary to overcome the

resistance in front of it due to the properties of the vessel. This fixed, the speed will then fix the number of revolutions, which will be found much greater than is usual in practice; and from this the size of the engines and boilers will be determined. Great saving in weight can be effected by careful design and judicious selection and adaptation of materials; also by the substitution of trussed framing and a proper mode of securing the engine to the structure of the vessel, as worked out in H. M. S. Nelson, by Mr. A. C. Kirk, of Glasgow, and in the beautifully designed engines by Mr. Thornycroft, in place of the massive cast iron bedplates and columns of the ordinary engines of commerce. The same may be said of the moving parts. In fine, the hull and engines should be as much as possible one structure; rigidity in one place and elasticity in others is the cause of most of the accidents so costly to the shipowner; under such conditions mass and solidity cease to be virtues, and the sooner their place is taken by careful design, and the use of the smallest weight of material—of the very best kind for the purpose—consistent with thorough efficiency, the better for all concerned. Coming to the question of the consumption of fuel, a considerable saving has been effected in nine years, as shown in the following table:

Item.	1872.	1881.
Working pressure, lb. per sq. in.	52.5	77.4
Heating surface per I.H.P. sq.ft.	4.64	3.919
Piston speed, feet per min.....	376	467
Coal burnt per I.H.P., lbs.....	2.11	1.828

This shows a saving equal to 13.38 per cent. in quantity of fuel consumed. Mr. Marshall then read a letter from Mr. Alfred Holt, of Liverpool, bearing on this subject, in which Mr. Holt spoke favorably of the single-crank engine, and stated his belief that the compound system would ere long be abandoned for the simple engine. He is endeavoring to feel his way to using the steam in one cylinder only, and so far the results have been encouraging; and he is now fitting a 2200-ton vessel on that system. He is also endeavoring to do without a crank shaft, the forward end of the screw shaft carrying an ordinary crank with overhung pin. This experiment also promises satisfactorily. In his opinion the great improvement of the immediate future is to increase the steam production of our boilers. A ton weight of a locomotive boiler produces as much steam as 6 tons of an ordinary steamboat boiler. Mr. Holt speaks of the coal account as one of the minor disbursements of a steamer. He does not give the ratio which coals bear to the total disbursements, but from other reliable sources Mr. Marshall found that, according to the direction of the voyage, it varies from 16 to 20 per cent.—or, say, an average of 18 per cent.—of the total disbursements, in a vessel carrying a cargo of 2500 tons. This will represent to day about £3000 per annum, and in 1872, at equal prices, the cost would have been £3750—showing a saving of £750, equal to a dividend of, say, 3 per cent. on the value of the ship. Again, the cost of coal per mile run for such a vessel in 1872 would have been at least 16½d.; to-day it does not exceed 13d. The marine boiler as now made is very efficient, but if the quantity of steam used be considered, in relation to the increased pressure, it will be seen that the boiler of to-day is little if any more efficient than that of ten years ago. The present boiler has an evaporative efficiency of about 75 per cent. and cannot be much improved so long as air is supplied to the furnace by the natural draught. To increase the efficiency from 75 to 82.5 per cent. would require about double the heating surface, the weight of boiler and water being also doubled, while the gain would only be 10 per cent. Mr. Blechynden's formula, used in Mr. Marshall's works for weights of cylindrical marine boilers of the ordinary type, and for pressures varying from 50 lbs. to 150 lbs., is as follows:

$$W = \frac{(P+15)\ (S+D^2L)}{C};$$

$$\text{or } W = \frac{2S\ (P+15)}{C}$$

when $S = D^2L$, which is a common proportion.

Here W = weight in tons.
P = working pressure as on gauge.
S = heating surface, in square feet.
D = diameter in feet.
L = length, in feet.

C=a constant divisor, depending on the class of riveting, &c. For boilers to Lloyd's rules, and with iron shells having 75 per cent. strength of solid plate, C=13,200.

This formula, if correct—and it is almost strictly so—would give the relative weight of boilers per sq. ft. of heating surface, for 105 lbs. and 150 lbs. total pressure, assuming we wish to increase the efficiency 10 per cent. as follows:

$$\text{Weight at 105 lbs.} = 105 \times \frac{1}{C}$$

$$\text{“ 150 “} = 150 \times \frac{1.75}{C} = \frac{263}{C}$$

$$\text{Hence the ratio of weight} = \frac{263}{105} = 2.5$$

In other words the boiler with the higher efficiency would weigh two and a-half times that with the lower efficiency. In the case of a vessel of 3000 tons, with engines and boilers of 1500 indicated horse power, the introduction of locomotive boilers with forced draught would place at the disposal of the owner 150 tons of cargo space, representing £1500 per annum in addition to the present earnings of such a vessel.

Mr. Thornycroft has for some years used the locomotive form of boiler for his steam launches, working them under an air pressure—produced by a fan discharging into a closed stokehold—of from 1-in. to 6-ins. of water, as may be required. The experiments made gave an evaporation of 7.61 lbs., of water from 1 lb. of coal at 212° Fah., with 2in. of water pressure, and 6.41 lbs. with 6 in. of pressure. These results are low; but it is to be remembered that the heating surface is necessarily small, in order to save weight, and the temperature of the funnel consequently high, ranging from 1073° at the first pressure and 1444° at the 6-in. With the ordinary proportions of locomotive practice the efficiency can be made equal to the best marine boiler, when working under the water pressure usual in locomotives, say from 3-in. to 4-in. including funnel draught. It has fallen to the lot of writer to fit three vessels recently with boilers worked under pressure in closed stokeholds. The results, even under unfavorable conditions, were very satisfactory. The pressure of air would be represented by 2 ins. of water, and the indicated horse-power given out by the engines was 2800, as against 1875 when working by natural draught, or exactly 50 per cent. gain in power developed.

Mr. Marshall then proceeded to refute the arguments which may be urged against the use of the locomotive boiler at sea, and which we need not reproduce. Coming to the engines, Mr. Marshall said that the total working pressure of to-day may be accepted as 105 lbs., or equal to seven atmospheres. If it were boldly accepted that eleven atmospheres, or 165 lbs., were to be the standard working pressure, the result would be a gain of 14.55 per cent., provided no counteracting influence came into play. Of course, there are forces which war against the attainment of the full extent of this advantage, viz., the greater condensation in the cylinders and loss in the receiver or passages. In regard to the former, it may be questioned whether by steam jacketing the high-pressure cylinder, correctly proportioning the steam passages, and giving a due amount of compression in both cylinders, this may not be reduced far below the generally received notion; and the latter cause of loss may be considerably reduced in its effect by a more carefully chosen cylinder ratio. The ratio usually adopted, between 3.5 and 4 to 1, whether the pressure be 70 lbs. or 90 lbs., may well be questioned. With a cylinder ratio of 2.95 to 1, the economic performance is very good, and equal to any with the higher ratio. A lower cylinder ratio has another advantage of considerable value, viz., that the working pressure can be much reduced as the boilers get older, while by giving a greater amount of steam the power may be maintained—at an extra cost of steam, of course, but not so great a cost as with higher ratios. The cut-off in the high-pressure cylinder usually takes place at about 0.6, and the ratio of expansion has decided the ratio of cylinders. The use of separate starting valves in both cylinders obviates that necessity. The difficulties in the way of taking advantage of the higher economic properties of greater pressures than hitherto used on board ship, are, it is submitted, not insuperable, and it would be to the interest of all that they should be firmly and determin-

edly met. It may be accepted as an average result that the Woolf engine, as usually arranged, will use 10 per cent. more steam than the receiver engine for the same power. Of the three-cylinder receiver type the data are insufficient to form a definite opinion upon; but so far the general working of the Arizona is stated to be as good, economically, as any of the two cylinder receiver class. The surface condenser remains as it was ten years ago, with scarcely a detail altered. In most engines it remains a portion of the framing, and as such adds greatly to the weight of the engine. It is a question seriously worth considera tion whether or no the surface of tubes can be reduced. The practice at present is to make the surface one-half the boiler surface as a minimum, that is, equal to about 2 square feet per indicated horse-power. In practice, the writer has found 1.4 square feet per indicated horse-power to maintain a steady vacuum of 27½ in.

Mr. Marshall has just completed six pairs of engines for three twin screw ships, having steel shafts of 10 in. diameter, and has in each case run the engines at 120 revolutions per minute, while indicating 1380 horse-power from each pair for ten to fifteen hours without stopping; and in no case has a single bearing or crank pin warmed or had water applied, the surface on examination being perfect. In these engines all working bolts, pins, and rods, except the piston and connecting rods, are of steel, all rods in tension being loaded to 8,000 lbs. per square inch. The boilers are of the Navy type, made throughout of Simens-Martin steel plates, riveted with steel rivets, all holes drilled. Furnaces are welded and flanged; the tubes are of brass. In comparison with an ordinary merchant steamer's iron boilers of the double-ended type, they weigh, including water and all appurtenances, as follows:

	Double-ended Type.	Navy Type.
Weight, tons.....	135 ..	146
I.H.P.....	1,400 ..	2,760
Draught.....	Natural ...	Forced

The screw propeller is still to a great extent an unsolved problem. We have no definite rule by which we can fix the most important factor of the whole, namely, the diameter. Mr. Froude has pointed out that by reducing the diameter, and thus the peripheral friction, we can increase the efficiency; and this is confirmed by cases—of Iris reduced 2 ft. 3 in., and the Arizona reduced 2 ft. This must of course be qualified by other considerations. The ship has by her form a definite resistance, and a certain speed is required; if the propeller be made too small in diameter, the ship will not be driven at the required speed, except at serious loss in other directions. This question was too large and complicated to be dealt with here, and should, in the first instance, be made the subject of careful and extended experiment, on which a separate paper should be written.

To sum up the whole: Progress has been made during the past nine years, and in the following particulars: (1) The power of the engines made and making show a great increase. (2) Speeds hitherto unattainable are now seen to be possible in vessels of all the various classes. (3) The consumption of fuel is reduced by 13.38 per cent. on the average; and numbers of vessels are now working on much less coal than that average, while the quality of the coal is in nearly all cases very inferior, so that it is not unfair to take credit for 20 per cent. reduction. (4) The working pressures of steam are much increased on the aver age, and still are increasing; many steamers now being built for 120 lbs. per square inch, while 90 lbs. is the standard pressure now required.

A NEW AIR PUMP.—The Pnéole is the name given to an ingenious pneumatic pump recently invented and described to the Academy of Sciences by M. F. de Romilly. It consists of a closed chamber or cylinder communicating by a side pipe with the receiver to be exhausted. In the top and bottom of the chamber two pipes project with their orifices opposite each other. The bottom pipe leads to a cistern, and a jet of water or other liquid is launched through it with considerable velocity by any convenient device, such as M. de Romilly's water elevator. This jet throws itself into the mouth of the pipe which projects from the roof of the chamber, and as this mouth is wider than the diameter of the jet, the water carries a considerable number of air bubbles with it from the chamber. Owing to their lightness these bubbles cannot return again, but must either follow the water which is led by a return pipe back to the cistern, or escape by means of a vent provided for them above the chamber. In this way the air within the chamber is drawn out and the receiver exhausted.

DETERMINATION OF THE EFFICIENCY OF LARGE CYLINDRICAL IRON TANKS.

By JOHN D. CREHORE.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

SOMETIME in the spring of 1868, in Cleveland, Ohio, a new wrought-iron tank 60 feet in diameter, and filled with water to the height of 18 feet, burst and fell asunder. The thickness of the single-riveted sheets composing this tank did not exceed three-sixteenths of an inch.

On the 29th of June, 1881, at Cincinnati, Ohio, a new iron water tank 48 feet in height and 100 feet in diameter, burst at a point 12 feet or more from the bottom and fell asunder, when filled to the estimated depth of about 40 feet. The riveted plates of which this tank was made, ranged in thickness from half an inch at bottom to a quarter of an inch at top, as stated in *Engineering News* of July 9th, 1881.

It would seem from the continued recurrence of such failures, that there is need of reiterating the teachings of the standard treatises on applied mechanics, or of emphasizing, to parties interested, the necessity of having the right specifications made before constructing; and of insisting upon carrying out such specifications strictly in honest execution.

Not having the actual complete data required for determining the strength of these two particular tanks, I give the ordinary mode of finding the requisite thickness of both single-riveted and double-riveted plates used in the construction of cylindrical tanks with vertical axes; and then apply the general expression to two cases where the diameters are 60 feet and 100 feet respectively.

Take 62.425 lbs. = weight of one cubic foot of water.

" .0361256 lbs. = weight of one cubic inch of water.

r=radius of cylinder base.

x=depth of water measured from surface.

Then the divellent force, due to water pressure, upon any elementary portion, or ring, of the height dx, is

$$dP=.0361256\times 2rxdx.$$

Therefore, after integrating between limits 0 and P, 0 and x, we have

$$P=.0361256rx^2, \quad . \quad . \quad . \quad . \quad . \quad (1)$$

which is the total force for the depth x, tending to send the sheets along any two diametrically opposite elements of the cylindrical surface.

But since this divellent force, for a given diameter, at a given point, varies with the height of water above that point, we have the simple formula

$$p=.0361256\times 2rx, \text{ lbs.} \quad . \quad . \quad . \quad (2)$$

which is the intensity of bursting force at any depth x, if r and x are in inches.

For the inch of depth next above the point x, we find from equation (1)

$$\begin{aligned}\Delta P&=.0361256\,r[x^2-(x-1)^2]\\&=.0361256\,r(2x-1)\end{aligned} \quad . \quad . \quad . \quad . \quad (3)$$

as the total divellent force for that inch. Now, since equation (2) gives the intensity at the bottom of this inch, it should be used instead of equation (3).

To resist the force p, of the water, we have for each inch of the depth, two plates of the thickness t inches each, and able to sustain with safety a tension of T pounds to the square inch of cross section. Therefore,

$$p=.0361256\times 2rx=2t\text{T}, \text{ lbs.} \quad . \quad . \quad (4)$$

$$t=\frac{.0361256rx}{\text{T}}, \text{ inches}, \quad . \quad . \quad . \quad (5)$$

It is plain that the safe allowed inch-strain, T, depends upon the quality of iron, the mode of riveting, and the workmanship thereof. Following with Rankine, the ordinary rules for riveted work to resist steam or water, we take:

"Diameter of a rivet for plates less than half an inch thick, about double the thickness of the plate.

"For plates half an inch thick and upwards, about once and a half the thickness of the plate."

Calling the ultimate resistance of good iron plates, to tension, equal to the ulti-

mate resistance of rivet-iron to shearing, we ought to have, for single-riveted sheets,

$$ct-2r_1t=\pi r_1^2$$

$$c=2r_1+\frac{\pi r_1^2}{t}, \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where c= distance between centers of consecutive rivets in a row,
r_1= semi-diameter of a rivet,
t= thickness of a plate,
all in inches.

For double-riveted sheets,

$$c=2r_1+\frac{2\pi r_1^2}{t}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

When the sheets are less than half an inch thick, we have $r_1=t$, and equation (6) becomes

$$c=t(2+3.1416)=5.1416t, \quad . \quad . \quad (8)$$

for single-riveted joints; and

$$c=t(2+6.2832)=8.2832t, \quad . \quad . \quad (9)$$

for double-riveted joints.

When the sheets are half an inch thick and upwards, $2r_1=\frac{3}{8}t$, $r_1=\frac{3}{4}t$,

$$c=t(1.5+\tfrac{9}{16}\pi)=3.2671t, \quad . \quad . \quad (10)$$

for single-riveted joints; and

$$c=t(1.5+\tfrac{9}{8}\pi)=5.0343t, \quad . \quad . \quad (11)$$

for double-riveted joints.

The plates are weakened by the simple removal of iron from the rivet holes, in the ratio

$$\frac{c-2r_1}{c}=\frac{\pi r_1^2}{2r_1t+\pi r_1^2}=\frac{3.1416}{5.1416}, \quad . \quad . \quad (12)$$

$$\therefore \quad T_1=15{,}000\times\frac{3.1416}{5.1416}=9{,}165,$$

for single-riveted sheets less than half an inch thick. And

$$\frac{c-2r_1}{c}=\frac{3.1416}{5.8082}, \quad . \quad . \quad (13)$$

$$T_1=15{,}000\times\frac{3.1416}{5.8082}=8{,}113,$$

thickness one-half inch or more.

Similarly, for double-riveted plates, the value of T is virtually reduced in the ratio

$$\frac{c-2r_1}{c}=\frac{2\pi r_1^2}{2r_1t+2\pi r_1^2}=\frac{3.1416}{4.1416} \quad . \quad . \quad (14)$$

$$\therefore \quad T_1=15{,}000\times\frac{3.1416}{4.1416}=11{,}379,$$

when $r_1=t$, and $t<\frac{1}{2}$ an inch.

But when $r_1=\frac{3}{4}t$, and t is not less than half an inch, T is virtually reduced in the ratio

$$\frac{c-2r_1}{c}=\frac{3.1416}{4.4749}, \quad . \quad . \quad . \quad (15)$$

$$\therefore \quad T_1=15000\times\frac{3.1416}{4.4749}=10.532.$$

The value of T, here taken for perfect unpunched plates, is one-fourth of 90,000 lbs., the assumed ultimate resistance of the iron as specified, thus rendering the so-called "factor of safety" equal to 4; whereas, in fact, 15,000 lbs. is doubtless a strain beyond one-half of that at the elastic limits, so that the real factor of safety here does not exceed 2.

From the *Cincinnati Commercial* of July 1, 1881, I quote the following extracts from the specifications for the large tank:

"The tank to be composed of twelve (12) rings of the best quality of fibrous boiler-iron plates, of a tensile strength of 60,000 pounds to the square inch. The annexed tables give the required thickness and weight of iron in pounds per square foot, and also the number, length, width and area for all the plates for the bottom of tank and for each ring in the circumference of the tank."

"All the vertical joints in the first six (6) rings of plates from the bottom upwards, to the double-riveted, known as "staggered" riveting; the remainder of the six (6) vertical joints as well as the horizontal joints in the bottom of the tank, to be riveted with a single row of rivets. The diameter, length and pitch of rivets corresponding to the thickness of plates, and width of laps for joints, are given in the annexed Table, No. 3."

As no tables are given, I am unable to assign the actual thickness of the plates, except as above stated in *Engineering News*.

I have therefore assumed, in case of the Cincinnati tank, that the thickness of plates varied uniformly from $\frac{1}{2}$ an inch at bottom to $\frac{1}{4}$ inch at top; and for the Cleveland tank have given the greatest, and probably uniform, thickness of $\frac{3}{16}$ of an inch.

Some local reporters of the disaster at Cincinnati call the burst reservoir a "steel" tank; but, as the specifications call for iron, I presume the contractors did not substitute steel.

Computing the required thickness, t, of the plates, by equation (5), the following table results:

Depth of water in feet. x	Radius of tank in feet. r	Kind of Riveting.	T=15,000 lbs., and within elastic limit.		T=30,000 lbs., and beyond elastic limit.		Supposed actual thickness.	
			T_1	Thickness of iron. t.	T_1	Thickness of iron. t.		
0	50	Single.	9,165	0. inches.	18,330	0. inches.	.25	inches.
4	"	"	"	0.114 "	"	0.0570 "	.2708	"
8	"	"	"	0.227 "	"	0.1135 "	.2917	"
12	"	"	"	0.341 "	"	0.1705 "	.3125	"
16	"	"	"	0.454 "	"	0.2270 "	.3333	"
20	"	"	8,133	0.640 "	"	0.3200 "	.3541	"
24	"	"	"	0.768 "	"	0.3840 "	.3750	"
28	"	Double.	10,532	0.691 "	22,758	0.3200 "	.3958	"
32	"	"	"	0.790 "	"	0.3657 "	.4167	"
36	"	"	"	0.889 "	"	0.4114 "	.4375	"
40	"	"	"	0.988 "	"	0.4572 "	.4583	"
44	"	"	"	1.087 "	"	0.5029 "	.4792	"
48	"	"	"	1.185 "	"	0.5486 "	.5000	"
0	30	Single.	9,165	0. "	18,330	0. "	.1875	"
4	"	"	"	0 0681 "	"	0.0341 "	"	"
8	"	"	"	0.1362 "	"	0.0681 "	"	"
12	"	"	"	0.2043 "	"	0.1022 "	"	"
16	"	"	"	0.2724 "	"	0.1362 "	"	"
20	"	"	"	0.3406 "	"	0.1703 "	"	"

It is apparent from my table, above given, that neither of these tanks gave a margin of safety so large as I have assumed. For having taken T=15,000, and the so-called factor of safety=4, the Cincinnati tank would fail to give this factor, with 20 feet of water, and the Cleveland tank would fail to give this factor with 12 feet of water.

Again, calling T=30,000, that is, the nominal factor of safety=2, but really taxing the iron beyond its elastic limit, the Cincinnati tank would fail to yield this factor at the center before being entirely filled; and the Cleveland tank would cease to give the factor 2 at the depth of 24 feet.

Now, all this assumes what is probably never completely realized in practice, viz.:

1. That the tensile strength of the plates, before punching, is 60,000 lbs. to the square inch of section.

2. That the remaining cross section of a plate, after the rivet holes have been punched, is equal to the cross section of the rivets.

3. That the rivets under their initial longitudinal strain, are still capable of sustaining sheering stress equal to the tensile strength of the plates.

4. That punching does not unfavorably affect the strength of the iron between the rivet holes.

5. That the distribution of strain is uniform on the remainder of plate, between two consecutive rivets.

6. That all rivets fill their holes and are perfect.

7. That the rivet holes are exactly opposite in the two plates, so that no "drifting" is required.

Taking into consideration all these things, it is easy to see how a so-called factor of safety of two, straining the iron past its elastic limit, would be used up, with consequent disaster.

Of course the thickness of plates near the top should be greater than the values of t found by the formula, and not less than the supposed actual values in the table. Although the pressure is greatest on the lowest rings, yet, owing to its connection with the bottom, failure occurs above this ring. Large high tanks should be properly braced and stiffened to resist the action of wind.

In Forbes' "Tourists" the capacity of the larger European churches and cathedrals is given as below: St. Peter's Church, Rome, holds 54,000; St. Paul's, London, 35,000; St. Sophia's, Constantinople, 33,000; Florence Cathedral, 24,300; St. Petronius, Bologna, 24,000; St. Paul's, Rome, 32,000; St. John Lateran, 22,900; Notre Dame, Paris, 20,000; the Pisa Cathedral, 13,000; St. Stephen's, Vienna, 12,400; St. Dominico's, Bologna, 12,000; St. Peter's, Bologna, 11,500; Cathedral of Venice, 11,000; Milan Cathedral, 7,000. These figures do not refer to seating capacity.

THE ACTUAL LATERAL PRESSURE OF EARTHWORK.

By BENJAMIN BAKER, M. Inst. C.E.

Proceedings of the Institution of Civil Engineers.

I.

The fact that a mass of earthwork tends to assume a definite slope, and that if this tendency be resisted by a wall or any other retaining structure, a lateral pressure of notable severity will be exerted by the earthwork on that structure, must have enforced itself upon the attention of constructors in the earliest ages. Many of the rudest fortresses doubtless had revetments, and of the hundreds of topes, or sacred mounds, raised in India and Afghanistan two thousand years ago, not a few afford examples of surcharged retaining walls on as large a scale as those occurring in modern railway practice. Nevertheless, long as the subject has occupied the attention of constructors, there is probably none other regarding which there exists the same lack of exact experimental data, and the same apparent indifference as to supplying this want. Thousands of pieces of wood have been broken in all parts of the world to determine the transverse strength of timber, whilst the experiments that have been undertaken to ascertain the actual lateral pressure of Earthwork are hardly worth enumerating. One authority after another has simply evaded the task of experimental investigation, by assuming that some of the elements affecting the stability of earthwork are so uncertain in their operation as to justify their rejection, and have so relieved themselves from further trouble. It would hardly be less logical to assume that because timber is liable to become rotten and possesses no strength at all, it was therefore unnecessary to conduct experiments in that case also. As a matter of fact, although these uncertain elements are neglected in investigations, engineers in designing, and still more contractors in executing, works, do not neglect them, nor could they do so without leading to a blameworthy waste of money in some instances, and to a discreditable failure in others. The result of the present want of experimental data is then simply that individual judgment has to be exercised in each instance, without that aid from careful experimental investigation which in these times is enjoyed in almost every other branch of engineering.

The mass of existent literature on the subject is both misleading and disappointing, for with little exception the bulk of it consists merely of arithmetical changes rung upon a century-old theory, which even at the time of its inception was put forward but as a provisional approximation of the truth, pending the acquirement of the necessary data. Writing some fifty years ago Professor Barlow excused his "very imperfect sketch of the theory of revetments, at least as relates to its practical application," on the ground that there was a "want of the proper experimental data;" and but comparatively the other day Professor Rankine had to write in almost identical terms: "There is a mathematical theory of the combined action of friction and adhesion in earth; but for want of precise experimental data its practical utility is doubtful." It is not, therefore, for want of asking that the missing data are not forthcoming. Indeed, the present desiderata could not have been more clearly formulated than they were half a century ago by Professor Barlow in the following words: "To render the theory complete, with respect to its practical application, it is necessary to institute a course of experiments upon a large scale; upon the force with which different soils tend to slide down when erected into the form of banks. A well-conducted set of experiments of this kind would blend into one what many writers have divided into several distinct data. Thus some authors have considered first, what they call the natural slope of different soils, by which they mean the slope that the surface will assume when thrown loosely in a heap; very different, as they sup-

pose, from the slope that a bank will assume that has been supported, but of which that support has been removed or overthrown. This, therefore, leads to the consideration of the friction and cohesion of soils, and what is denominated the slope of maximum thrust; but, however well this may answer the purpose of making a display of analytical transformations, I cannot think it is at all calculated to obtain any useful practical results. I should conceive that a set of experiments, made upon the absolute thrust of different soils, which would include or blend all these data in one general result, would be much more useful, as furnishing less causes of error, and rendering the dependent computations much more simple and intelligible to those who are commonly interested in such deductions."

A knowledge, however imperfect, of the actual lateral pressure of earthwork, as distinguished from what may be termed the "text-book" pressures, which, with hardly an exception known to the author, are based upon calculations that disregard the most vital elements existent in fact, is of the utmost importance to the engineer and contractor. It affects not merely the stability of retaining walls, but the strength of tunnel linings, the timbering of shafts, headings, tunnels, deep trenches for retaining walls, and many other works of every-day practice. The vast divergence between fact and theory has perhaps impressed itself with peculiar force upon the author, because, having had the privilege of being associated with Mr. Fowler, Past President of the Inst. C.E., during the whole period of the construction of the "underground" system of railways, he has had the advantage of the experience gained in constructing about 9 miles of retaining walls, and, in relation to the subject of the present paper, the still more valuable experience of 34 miles of deep-timbered trenches for retaining walls, sewers, covered ways, and other structures. A timber waling is a sort of spring, rough it may be, but still the deflections when taken over a sufficiently large number of walings afford an approximate indication of the pressure sustained—an advantage which a retaining wall does not possess. Again, though numberless retaining walls have failed, in ninety-nine cases out of hundred the failures have been due to faulty foundations, and, consequently, experiences of this sort seldom afford any direct evidence as to the actual lateral pressure of earthwork. In timbered trenches, on the other hand, the element of sinking and sliding foundations does not so frequently arise to complicate the investigation.

All kinds of earth were traversed by the above 34 miles of trenches, from light vegetable refuse to the semi-fluid yellow clay, which at different times has crushed in so many tunnel linings in the northern districts of the metropolis. The heights of the retaining walls ranged up to 45 feet, the depths of the timbered trenches to 54 feet, and the ground at the back of the former was in many cases loaded with buildings ranging up to 80 feet in height. Possibly some of the author's observations and conclusions in connection with these and other works of a similar character may be of interest to engineers, though the information he is able to contribute, having been obtained chiefly in the ordinary routine of his practice and not in specially devised investigations, must necessarily form but a very imperfect contribution to the data which have been asked for so long.

The theory underlying all the multitudinous published tables of required thickness for retaining walls is, that the lateral pressure exerted by a bank of earth with a horizontal top is simply that due to the wedge-shaped mass, included between the vertical back of the wall and a line bisecting the angle between the vertical and the slope of repose of the material. If this were true in practice, all such problems could be solved by merely drawing a line on the annexed diagram, in which *a b d c* is a square, *a b g* a triangle, having the sides of the ratio of 1: $\sqrt{\frac{1}{3}}$, and *a h d* a parabolic curve.*

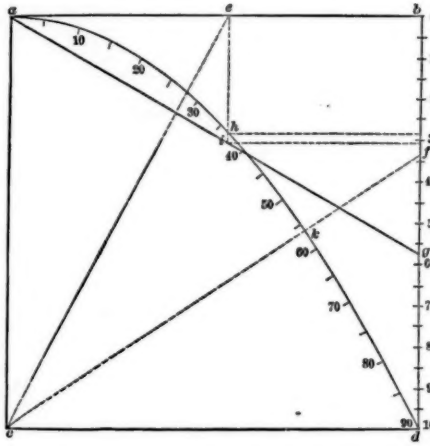
Thus, if it were required to know the lateral pressure per square foot of earth-

*For earthwork and masonry of the same weight per cubic foot the equation for stability is:

$$\frac{ht^2}{2}=\frac{h^3}{6}\tan^2 \tfrac{1}{4} \text{ angle.}$$

Hence, the required thickness (t_1) in terms of the height (h) will be $t_1=\sqrt{\frac{1}{3}}\tan \frac{1}{4}$ angle, which is represented on the diagram by the line $a-g$; and the "equivalent fluid pressure" in terms of that of a cubic foot earthwork will be $=\tan^2 \frac{1}{4}$ angle, which is represented by the parabolic curve $a\,h\,d$.

work, having a slope of repose of $1\frac{1}{2}$:1, and the thickness of rectangular vertical wall which, when turning over on its outside edge would just balance that pressure, it would merely be necessary to draw the line $c\ f$ at the given slope of



$1\frac{1}{2}$:1 and the line $c\ e$ bisecting the angle $a\ c\ k$, when the line $e\ h$ would give the equivalent fluid pressure in terms of that of a cubic foot of the earth=28.7 per cent., and the line $e\ i$ the thickness of the rectangular wall in terms of the height=31 per cent, the weight of masonry being the same as that of the earth.

Common stocks in mortar and ballast backing each weigh about 100 lbs. per cubic foot, hence, on the preceding hypothesis, the pressure acting on the wall wolud be the same as that due to a fluid weighing 28.7 lbs. per cubic foot. If, as is usually the case, the masonry be heavier than the earthwork, the required thickness of wall would be reduced in inverse proportion to the square root of the respective weights, so that should the masonry weigh 10 per cent. more than the ballast, the thickness would be about 5 per cent. less than before, or, say, 29.5 per cent. of the height.

For other slopes of repose the equivalent fluid pressure and thickness of wall for materials of equal weight would be as follows:

Ratio of horizontal to vertical	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3
Fluid pressure	5.6	7.7	10	12.4	14.8	17.2	19.6	22	24.3
Thickness	.136	.160	.182	.203	.222	.239	.256	.27	.284

Ratio of horizontal to vertical	1.4	1.5	1.6	1.7	1.8	2	3	4	8
Fluid pressure	26.5	28.7	30.7	32.6	34.6	38.2	52	61	100
Thickness	.297	.31	.32	.33	.34	.357	.416	.451	.578

In the thickness tabulated above no allowance has been made for the crushing action on the outer edge; in practice the batter usually given to the face of the wall more than compensates for this action if the mean thickness be that given in the table. No factor of safety is included, but according to theory the wall in each case would be just on the balance. Any one accustomed to deal with works of this class will, however, know that in practice walls so proportioned would in the majority of cases possess a large factor of safety.

Doubtless many engineers will, with the author, have noticed that laborers and others not infrequently carry out unconsciously a number of valuable and suggestive experiments on The Actual Lateral Pressure of Earthwork. In stacking materials, rough-and-ready retaining walls, made of loose blocks of the same material, are often run up, and as it is generally of little moment whether a slip occurs or not, the workmen do not trouble about factors of safety, but expend the least amount of labor that their every-day experience will justify, and so a tolerably close measure is obtained of the average actual pressure of material retained. When the wood paving was recently laid in Regent

Street, the space being limited, the stacked wooden blocks in many cases had to do duty as retaining walls to hold up the broken stone ballast required for the concrete substructure. In one instance (Ex. 1) the author noted that a wall of pitch-pine blocks, 4 feet high and 1 foot thick, sustained the vertical face of a bank of old macadam materials which had been broken up, screened, and tossed against this wall until the bank had attained a height of 3 feet 9 inches, a width at the top of about 5 feet, and slopes on the farther sides deviating little from 1.2 to 1. Now, referring to the diagram and table of thickness, it will be seen that according to the ordinary theory the thickness of wall which would just balance the thrust of a bank 3 feet 9 inches high of material having a slope of repose of 1.2 to 1 would be $3.75 \times .27 = 1.01$, or, say, 1 foot, which is the actual thickness of the given wall. But in the table the specific weight of the material in the wall and backing is assumed to be the same, whereas in the present case the weight of the pitch-pine block wall, allowing for the height being greater than that of the bank, would only be, say, 46 lbs. $\times \frac{4 \text{ feet}}{3.75 \text{ feet}} = 49$ lbs. per cubic foot, whilst that of the broken granite bank would be, say, 168 lbs. less 40 per cent. for interstices = 101 lbs. per cubic foot. It follows, since the wooden wall stood, that if it had been made of materials having the same weight per cubic foot as the bank, the retaining wall would not have been on the point of toppling over, as the ordinary theory would indicate, but have possessed a factor of safety of at least $\frac{101 \text{ lbs.}}{49 \text{ lbs.}}$, or, say, 2 to 1. The effective lateral pressure of the earthwork in this instance consequently could not have exceeded a fluid pressure of $\frac{22 \text{ lbs.} \times 49}{101} = 10.7$ lbs. per cubic foot, instead of the 22 lbs., which theoretically corresponds to the given slope of 1.2 to 1.

Taking another case, in which the wall, instead of being lighter than the bank, was much heavier, the same conclusion still holds good. In this instance (Ex. 2) the author found a wall of slag blocks having a batter of $\frac{1}{10}$ of the height, and an effective thickness of 1 foot sustained a bank of broken slag 10 feet high, with a surcharge of some 5 feet more. The battering wall, with a thickness of $\frac{1}{10}$ of the height, would have the same stability as a vertical wall 0.173 thick, and the lateral pressure of the surcharged bank with the battering face would be practically the same as that of a horizontal-topped bank with a vertical face; hence, since the relatively closely-packed slag blocks constituting the wall would weigh about 40 per cent. more than the broken slag of the bank, the thickness of a vertical wall built of materials of the same weight as the bank, and having the same stability as the wall under consideration would be $= \sqrt{1.4} \times 0.173 = 0.205$ of the height. Referring to the table, the figure 0.205 will be found to apply to a slope of repose of 0.8 to 1, whereas the actual slope in the instance of this slag was 1.33 to 1. For the latter slope the thickness theoretically should have been 0.29, and since the stability varies as the square of the thickness, it follows that with the thickness indicated by theory, the wall, instead of being just on the balance, would have possessed a factor of safety of at least $\frac{0.29^2}{0.205^2}$, or 2 to 1, as in the last example.

Other instances of these unintentional experiments on the lateral pressure of earthwork will be found in the stacking of coal in station yards, in the rubbish banks at quarries, and in many other instances which have been investigated by the author, with the invariable result of finding that walls which, according to current theory, would be on the point of failure, really possess a considerable factor of safety.

Turning now from indirect to direct experiments, specially arranged with a view to determine the lateral pressure of earthwork, those carried out at Chatham nearly forty years ago by Lieutenant Hope, R.E., may be referred to. His intention was to experiment first with fine dry sand, as free as possible from the complications introduced by cohesion, irregularities of mass and other practical conditions, and then to extend the investigation to ordinary shingle, and to clay and other soils possessed of great

tenacity. Sand and shingle were, however, alone experimented with.

The direct lateral thrust of sand weighing 91 lbs. per cubic foot when lightly thrown together, and 98½ lbs. when well shaken, was measured by balancing the pressure exerted on a board 1 foot square. The mean results of seven experiments (Ex. 3) was 9 lbs. 7 oz., which is that due to a fluid weighing nearly 19 lbs. per cubic foot. As the slope of repose of the sand employed was 1.42 to 1, the theoretical fluid pressure due to the weight of 98½ lbs. per cubic foot would be 26.2 lbs., or about 40 per cent. more than the observed 19 lbs. per cubic foot.

With gravel (Ex. 4) weighing 95½ lbs. per cubic foot, and having a slope of repose of 1⅓ to 1, about the same lateral pressure was found to exist. Lieutenant Hope attempted to reconcile the difference between theoretical and actual results by adding to the measured force an estimated sum for friction against the sides of the apparatus, but experiments of the author's to be subsequently referred to, clearly prove that the difference is not to be so accounted for. Indeed, the knowledge of what the pressure theoretically should be would appear to have given Lieutenant Hope an unconscious bias in the direction of rather exaggerating the experimental results. This it is extremely easy to do, as a trifling amount of vibration will alter the pressure from 10 to 50 per cent., and a comparatively innocent shake in a small model will correspond in its relative effects with an earthquake in real life.

Experiments with colored sand in a vessel with glass sides did not uniformly confirm the usual theory that the angle of pressure of maximum thrust is half that contained between the natural slope and the back of the wall (Ex. 5). Thus the line of separation was at an angle of 24° with the vertical instead of 28°. Again, with a gravel bank (Ex. 6) 10 feet high the line of separation ranged from 3 feet 8 inches to 5 feet 8 inches from the back of the wall, whilst as the natural slope was 1⅓ to 1, the distance should have been 5 feet in all instances if Coulomb's theory applied strictly to even such exceptionally favorable materials as dry sand and shingle.

The really valuable portion of Lieutenant Hope's investigation was the series of experiments on walls built of bricks laid in wet sand. The first of these (Ex. 7) was about 20 feet long and two-and-a-half bricks, or say, 1 foot 11 inches thick. When raised to a height of 8 feet and backed with ballast, it had inclined from the vertical about 1½ inch; at 9 feet the inclination had increased to 3¼ inches, and at 10 feet the wall fell forward in one mass. At the instant when the thrust of the ballast overcame the stability of the wall, the overhang must have been 4 inches, and the moment of stability per lineal foot certainly not more than 2,000 lbs. $\times$ 0.9 foot = 1,800 foot-pounds. Hence, dividing by $\frac{h^3}{6}$, is obtained 10.8 lbs. per cubic foot as the weight of the fluid, which would have exerted a lateral pressure equal to that of the ballast piled against this 10-feet wall. This is hardly more than half the pressure obtained with the 1-foot square board, and shows how desirable it is that even the most faithful experimenter should not know what to expect if a mere shake of a table will enable him to obtain the desired result. The natural slope of the ballast being 1⅓ to 1, and the weight 95½ lbs. per cubic foot, the pressure theoretically should have been 23.6 lbs. per cubic foot instead of 10.8 lbs.; hence a wall so proportioned as to be on the point of toppling over, according to the ordinary theory, would in this instance have had a factor of safety of rather more than 2 to 1.

Another vertical wall (Ex. 8) was constructed with the same amount of materials differently disposed. At 8 feet high, after heavy rain, the 18-inch thick panel between the 27-inch deep counterforts had bulged 1¼ inch; at 12 feet 10 inches the bulging had increased to 4½ inches, and the overhang at the top to 7½ inches, when, after some hours' gradual movement, the wall fell. The moment of stability at the time of failure could not have exceeded 2,600 lbs. $\times$ 1 foot = 2,600 foot-pounds, which, divided by $\frac{h^3}{6}$, gives 7.4 lbs. per cubic foot, instead of the theoretical 23.6 lbs., as the weight of the equivalent fluid. This result is clearly not evidence that the pressure of the ballast was less in the counterforted

wall than in the wall of uniform thickness, but that the binding of the ballast between the counterforts increased the stability of the wall by practically adding somewhat to its weight.

A wall with a batter of $\frac{1}{8}$ of the height, and with counterforts of the same thickness as the last (Ex. 9), was next tried, with noteworthy results. This wall, only 18 inches thick, with counterforts 3 feet 9 inches deep, measuring from the face of the wall, and 10 feet apart, was carried to a height of 21 feet 6 inches without any indications of movement, beyond a bulging about halfway up of $2\frac{1}{4}$ inches at the panel, and $1\frac{1}{2}$ inch at the counterfort; and in Lieutenant Hope's opinion it would probably have stood for years without giving way any more, although the mean thickness was less than $\frac{1}{10}$ of the height. The calculated stability indicates that a fluid pressure of 8.5 lbs. per cubic foot would have overturned the wall, and, correcting for the reduced thrust of the ballast due to the batter of its face, the equivalent pressure on a vertical wall would be that of a fluid weighing 10 lbs. per cubic foot.

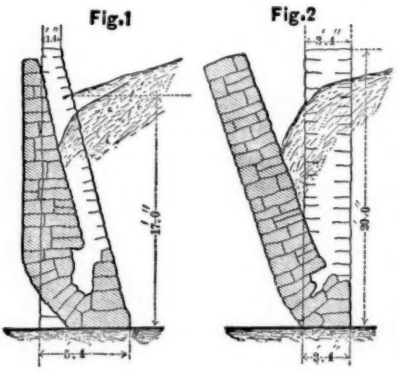
Here, again, doubtless the binding of the gravel between the counterforts contributed to the stability of the wall; but, even adopting the extreme and impossible hypothesis that the ballast was as good as so much brickwork, or, in other words, that the wall was a monolithic structure of the uniform thickness of 3 feet 9 inches, its stability would barely balance the 23.6 lbs. per cubic foot fluid pressure theoretically due to the weight and slope of repose of the backing. Assuming that the binding of the ballast between the counterforts increased the stability, as in Examples 8 and 9, by about 45 per cent., the fluid resistance would be 14.5 lbs. per cubic foot; and, remembering that this wall did not fall, though the bricks were only laid in sand, it is reasonable to infer that this interesting experiment confirms the previous conclusion that a properly built wall in mortar or cement, just balancing the theoretical pressure, would really have had a factor of safety of 2 to 1. Other experiments of Lieutentant Hope's justify this inference, and so do the experiments of General Pasley, also made at Chatham many years ago.

General Pasley experimented with loose dry shingle weighing 89 lbs. per cubic foot, and having a natural slope of $1\frac{1}{4}$ to 1. His model retaining walls (Ex. 10) were 3 feet long, 26 inches high, of various forms and thickness, and weighed 84 lbs. per cubic foot. The stability of each wall was tried by pulling it over by weights before and after backing it up with shingle, and the difference between the two pulls of course represented the thrust of the shingle. When the thickness of the vertical wall was 8 inches, the stability, without shingle, was equivalent to a pull of 47 lbs. applied at the top of the wall, and with shingle, the pull required to upset it was reduced to 30 lbs. The difference of 17 lbs. represents the thrust of the shingle, and throughout the several hundreds of experiments this appears to have been comprised within the limits of 16 lbs and 24 lbs. The center of pressure being at $\frac{1}{3}$ of the height of the wall, the mean thrust of 20 lbs. at the top will be equivalent to 60 lbs. at the center of pressure, and the area being 6.5 square feet, and the height 26 inches, the actual lateral pressure of the shingle, as deduced from General Pasley's experiments, is equivalent to that of a fluid weighing 8.5 lbs. per cubic foot, instead of 21 lbs. as theory would indicate.

General Cunningham tested some model revetments, and his experiments led him to believe that General Pasley had overestimated the thickness required for stability. The models, in this case about 30 inches in height, were weighted with earth and musket bullets to the equivalent of an equal mass of masonry weighing 129 lbs. per cubic foot. One of the models (Ex. 11) represented a wall 30 feet high, 6 feet thick at the base, vertical at the back, battering 1 in 10 on the face, with counterforts 4 feet 3 inches thick, 18 feet from center to center, and of a depth equal to the thickness of the wall or, say, 3 feet at the top and 6 feet at the base. This was backed up and surcharged with shingle weighing 104 lbs. per cubic foot, but required a pull of 111 lbs. to overturn it. Another model (Ex. 12) representing a wall 18 feet high, 4 feet 4 inches thick at the base, and 2 feet 8 inches thick at the coping, without counterforts, when surcharged with shingle to a height greater than that of the wall, required a

pull of 84 lbs. to upset it. A fluid pressure of 19 lbs. per cubic foot would overcome the stability of such a wall; hence, having regard to the surcharge and to the pull, it will be found that the actual lateral pressure of the shingle could not have exceeded that due to a fluid weighing 8 lbs. per cubic foot.

General Burgoyne also commenced an experimental investigation of the question of retaining walls, but circumstances precluded his pursuing the subject. About half a century ago he built at Kingstown four experimental walls 20 feet long and 20 feet high, having the same mean thickness of 3 feet 4 inches, or $\frac{1}{6}$ of the height, but differing otherwise. One of them (Ex. 13) was of the uniform thickness of 3 feet 4 inches, and battered $\frac{1}{2}$ of the height; another (Ex. 14) was 1 foot 4 inches thick at the top, and 5 feet 4 inches at the bottom, with a vertical back; the third (Ex. 15, Fig. 1) was of



the same dimensions, with a vertical front; and the last (Ex. 16, Fig. 2) was a plain rectangular vertical wall 3 feet 4 inches thick. The masonry consisted simply of rough granite blocks laid dry, and the filling was of loose earth filled in at random, without ramming or other precautions, during a very wet winter. No. 1 wall stood perfectly, as might have been expected from the behavior of Lieutenant Hope's experimental wall of nearly the same height and batter. No. 2 wall also stood well, coming over only about 2 inches at the top. A fluid pressure of 22.5 lbs. per cubic foot would be required to overcome the stability of this dry masonry wall weighing 142 lbs. per cubic foot. Earthwork of the class described, consolidated during continuous rain, would not weigh less than 112 lbs. per cubic foot, nor have a slope of repose less than $1\frac{1}{2}$ to 1. Referring to the table, the theoretical pressure of such earthwork would be $28.67 \times 1.12 = 32$ lbs. per cubic foot, or nearly one-half greater than the wall could resist.

No. 3 and No. 4 walls both fell when the filling had attained a height of 17 feet. The former came over 10 inches at the top, was greatly convex on the face, overhanging 5 inches in the first 5 feet of its height and rending it in every direction, when finally it burst out at 5 feet 6 inches from the base, and about two-thirds of the upper portion of the wall descended vertically until it reached and crushed into the ground (Fig. 1). The vertical wall tilted over gradually to 18 inches and then broke across, as it were, at about $\frac{1}{4}$ of its height and fell forward (Fig. 2). So long as the wall remained vertical the calculated stability would indicate it to be equal to sustain the pressure of a fluid weighing 20.4 lbs. per cubic foot, but the overhang of 18 inches and the bulging which occurred would reduce the stability exactly one-half, so that a fluid pressure of 10.2 lbs. would really have sufficed to effect the final overthrow. The character of the failure both of No. 3 and No. 4 walls clearly indicates that if the walls had been in mortar or cement, as usual, the overhang would not have been a fraction of that occurring with the dry stone walling, and the failure would not have taken place. Since, as already stated, the theoretical thrust of the earthwork would be 32lbs. per cubic foot, it is hardly unfair to conclude that a wall in mortar and proportional to that pressure would not have come over and would have enjoyed a factor of safety of at least 2 to 1.

Colonel Michon carried out in 1863 an interesting experiment (Ex. 17) on a 40 feet high retaining wall of a peculiar type (Figs. 3 and 4), which, perhaps, may be best described as a very thin wall with numerous battering buttresses turned upside down. The face wall, battering 1 in 20, was only 1 foot 8 inches thick, and the buttresses, spaced about 5 feet apart from center to center, were also 1 foot 8 inches thick by 2 feet 4 inches

deep at the base and 9 feet 2 inches at the top. The work was hurriedly constructed during continuous rains with any stones that came to hand, and with very bad lime. When the filling had attained a height of 29 feet the wall bulged a trifle, but no further movement was noticed, though the filling, when carried up to the top of the coping, was allowed some weeks to settle in the

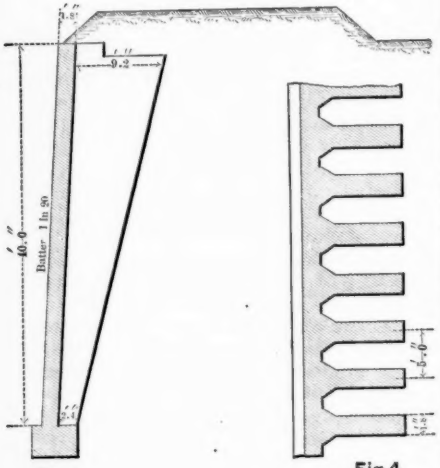


Fig.3

Fig.4

rain. Earth was then piled above the level of the coping to a height of between 3 and 4 feet, when the wall fell. The fall was preceded by a general dislocation of the masonry at the base, a bulging at about one-third of the height, and a slight movement of the top towards the bank. The lower portion of the wall fell outwards, the upper part dropped vertically (as in General Burgoyne's wall, Fig. 1), and a considerable number of the counterforts went forward with the slip and even maintained their vertical position.

This failure arose from a flexure of the thin wall at the center of pressure of the earthwork, and would not have occurred had the masonry been in cement instead of in weak unset lime. No direct data therefor are afforded for an exact estimate of the actual lateral thrust of the heavy wet filling on this lofty wall. Nevertheless, as the weight of the masonry was only 18,000 lbs. per lineal foot, and the center of gravity of the same from the toe but 6 feet 6 inches, it follows that the wall, even if monolithic, would be overturned with the pressure of a fluid weighing 11 lbs. per cubic foot. How far the sodden earthwork between the counterforts contributed to the stability of the wall is open to question, but it could hardly account for the difference between the 11 lbs. or less stability and the 32 lbs. due, according to the ordinary theory, to the weight and slope of the backing. If dirt were as good as masonry, General Burgoyne's wall with the battering back (Fig. 1) would have been more stable than the vertical wall (Fig. 2) in the ratio of the squares of their respective bases, or, say, as $2\frac{1}{2}$ to 1, whereas, these walls proved to be of equal stability, both falling with 17 feet of filling. Colonel Michon, by assuming dirt to be as good as masonry, and a wall 40 feet high and 1 foot 8 inches thick of unselected stones and unset mortar to be as good as a monolith, succeeds in reconciling the behavior of his wall with the ordinary theory of the stability of earthwork; but in the author's experience the conditions assumed are not approached in practice. The stability of this lofty wall battering only $\frac{1}{20}$ of the height on the face, and averaging hardly more than $\frac{1}{12}$ of the height in thickness, is, nevertheless, one of the most remarkable and interesting facts connected with the subject of the present paper.

To show how invariably an experimentalist is driven to the same conclusion as to the excess in the theoretical estimate of the pressure of earthwork, the "toy" experiments of Mr. Casimer Constable with little wooden bricks and peas for filling may be usually referred to. The peas took a slope of 1.9 to 1, and weighed twice as much per cubic foot as the wooden retaining wall. By the table the thickness of wall, which would just balance the lateral pressure would be $.35\sqrt{2}=.49$ height. By experiment, a wall (Ex. 18) having a thickness of .40 height moved over slightly, but took some amount of jarring to bring it down. Since the stability varies as the square of the thickness, the calculated wall would be 50 per cent. more stable than the actual wall, without considering the question of jarring. If the

slope of the peas had been measured also, after jarring, it would probably have been found to be nearer 2.9 to 1 than 1.9 to 1, and the calculated required thickness would have been correspondingly increased.

The influence of even a slight amount of vibration is well illustrated by the difference between the co-efficient of friction of stones on one another in motion and repose. Granite blocks, which will start on nothing flatter than 1.4 to 1, will continue in motion on an incline of 2.2. to 1, and, for similar reasons, earthwork will assume a flatter slope and exert a greater lateral pressure under vibration than when at rest. This fact has long received practical recognition from engineers; indeed, attention was called to it by Mr. Charles Hutton Gregory, C. M.G., Past-President Inst. C.E., in a Paper on slips in earthwork, read before the Institution in 1844, when the President and others gave instances of slips in railway cuttings caused by vibration;

The general results of the preceding and other independent experiments on retaining walls tending to throw a doubt on the accuracy of Lieutenant Hope's measurement of the direct lateral thrust of ballast and sand on a board 1 foot square, the author considered it advisable to repeat those experiments. Care was taken to eliminate all disturbing causes tending to vitiate the results. The pressure board was held by a string at its center of pressure, and was perfectly free to move in every direction, which, of course, a retaining wall having a greater hold on the ground than stability to resist overturning has not. In every instance the filling was poured into the box and allowed to assume its natural slope towards the pressure board, and the latter was rotated and thumped to keep the ballast alive before the reaction was measured. In order to avoid all chance of the bias which the knowledge what to expect might have given him, as it did Lieutenant Hope, the author had the experiments made by others who were ignorant even of the object of them, whilst he himself purposely experimented with an apparatus the dimensions of which he did not know, and consequently could form no estimate of the weight which would be required in the scale

With clean dry ballast having a natural slope of $1\frac{1}{3}$ to 1, it will be remembered Lieutenant Hope obtained a lateral pressure on 1 square foot of 9 lbs. 7 oz. With well-washed wet ballast of the same kind the author found the natural slope to be $1\frac{1}{3}$ to 1, and he decided therefore to use the ballast wet, because, possessing greater fluidity, it would give more uniform results than dry ballast, and also impose greater lateral pressure. In a large number of independent experiments the results were uniformly as follows (Ex. 19): With 6 lbs. in the scale the board moved forward about $\frac{1}{2}$ inch, but continued to retain the ballast; with 7 lbs. very slight movement occurred; with 8 lbs., no movement at all; and with 10 lbs., under extreme vibration, the board moved forward about as much as it did with 6 lbs. without vibration. The general opinion of the different experimentalists was, that the fair value of the lateral pressure of this wet ballast was 7 lbs., because when that weight was in the scale pad a slight jolt was sufficient to let the ballast down by the run to a slope of $1\frac{1}{2}$ to 1. The board being 1 foot square, this of course is equivalent to the pressure of a fluid weighing 14 lbs. per cubic foot, instead of the 19 lbs. obtained by Lieutenant Hope, and the 26 lbs. indicated by theory.

With the same ballast unwashed and mixed with slightly loamy pit sand (Ex. 20) the natural slope was 1 to 1, without vibration, and $1\frac{1}{4}$ to 1 with a moderate amount of vibration. A weight of 3 lbs. was as effective in retaining this ballast as 6 lbs. in the former instance; 4 lbs. held it under a moderate amount of vibration, but $3\frac{1}{2}$ lbs. failed to hold the board under very little. Practically speaking, the lateral thrust was about half that with the clean wet ballast, and considerably less than half that theoretically due to the slope of repose of the loamy ballast.

In harbor works both walls and backing are frequently completely immersed, and, so far as gravity is concerned, stone blocks and rubble become then transformed into coal. The author, therefore, experimented (Ex. 21) with some coal having a peculiarly "greasy" surface, and offering the advantage of exceptional fluidity. With 3 lbs. the board moved forward about 1 inch, but no more until a slight jar was applied, when it

fell; with 4 lbs. a moderate amount of vibration also generally caused failure; with 5 lbs. the board usually moved forward gradually without making a rush so long as a tolerably considerable amount of vibration was maintained. When a slip occurred the slope was invariably $1\frac{3}{4}$ to 1. The coal proved to be more sensitive to vibration than the wet ballast, and still more so than the unwashed ballast. A weight of 4 lbs. with the coal appeared to be equivalent to 7 lbs. with the washed and $3\frac{1}{2}$ lbs. with the unwashed ballast. The weight of the coal being one-half that of the wet ballast, and the respective slopes of repose being $1\frac{3}{4}$ and $1\frac{1}{2}$ to 1, the lateral thrusts would theoretically be as 16.8 : 28.7, which is practically the exper imental result of 4 to 7.

The author having occasion to design a solid pier 42 feet in height from the bottom of the harbor to the surface of the quay, where a soft bottom of great thickness and small consistency precluded the use of concrete block or other retaining wall, adopted an arrangement in which an iron grid of rolled joist, with a backing of large blocks of rubble, was substituted for a wall. It was necessary, therefore, to know the lateral thrust of large blocks of stone in such a structure, and mistrusting theoretical deductions, the author made direct experiments on a model to a scale of 1 inch to the foot.

In this instance the individual stones were intended to be fairly uniform in size, and of lateral dimensions not less than $\frac{1}{20}$ of the height of the wall, so that the conditions differed considerably from those assumed in theoretical investigations. A number of billiard balls exactly superimposed in a tightly fitting box would exert no thrust though their slope of repose might be as flat as 3 to 1; and it is not quite clear how nearly or remotely large boulders in an iron cage approximate to that condition. The stones used in the experiment were waterworn pieces of schistose rock having a "greasy" surface and a slope of repose of $1\frac{1}{2}$ to 1. This inclination was found by the author to obtain in natural slopes of all heights, from the pile of metalling by the roadside to the hills themselves. He ascended one slope of $1\frac{1}{2}$ to 1, over 500 feet in height, and found the balance was so nearly maintained that a footstep at times would set many tons of stones in motion; and a few winters ago a couple of stones of the respective weights of 18 tons and 22 tons, descended this slope and acquired sufficient momentum to carry them across a road at the foot of the slope and on to the middle of the lawn in front of an adjoining shooting lodge.

The conditions of the material were thus favorable, as in the instance of the coal, for obtaining uniform results and a maximum lateral thrust. In order to exclude all possible influence from side friction, the length of the box was made four times the height of the wall. As the result of ten experiments (Ex. 22) it was found that a weight in the scale corresponding to the pressure of a fluid weighing 10.2 lbs. per cubic foot sufficed to retain the rubble, though the face planking moved forward slightly as the last few shovelfuls were thrown against it. The weight of the stone filling was 98 lbs. per cubic foot, or practically the same as that of the wet ballast last referred to; so the 10.2 lbs., or say under slight vibration 11 lbs., in the present instance compares with the 14 lbs. of the previous instance, and the difference is a measure of the influence of large-sized, smooth-faced boulders as compared with ordinary ballast.

With coal of the same size (Ex. 23) the equivalent weight of fluid was 6 lbs. per cubic foot, which confirms the preceding result when regard is had to the respective weights and slopes of repose of the two materials. The experiments collectively proved that a wall, which according to the ordinary theory would be on the point of being overturned by the thrust of a bank of big boulders, would in fact have a factor of safety of nearly $2\frac{1}{2}$ to 1.

REPORTS OF ENGINEERING SOCIETIES.

THE IRON AND STEEL INSTITUTE.—The Autumn Meeting of the Iron and Steel Institute of Great Britain will be held in London on the 11th and three following days of October. An influential committee has been formed in London for the purpose of making arrangements for the reception and entertainment of the Institute. A programme of the proceedings will appear in due course.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The last number of Transactions contains the address of President Francis, already published in this magazine; also minutes of

the June meetings of the Society and of the Board of Direction. In addition to the above are the following important reports:

Report of the Committee on the Engagement of Civil Engineers on Government Works.

Report of Committee on Uniform Method of Tests of Cement.

Report of Committee on Tests of Iron and Steel.

Report of Committee on Gauging of Streams.

A very important report upon experiments upon Thenix columns has been presented to the Society, and is in course of preparation.

ENGINEERING NOTES.

THE GARABIT VIADUCT.—The Garabit viaduct, the construction of which has recently been commenced, is on the line of the Marvejols-Neussargues railway, crossing the valley of the Trueyre, at an elevation of 412 feet above low-water mark, where the valley is 1,800 feet wide. In M. Eiffel's design, a large arc, like that of the Douro viaduct, but a little larger, is employed. The height is limited to 262 feet (80 meters) of which there are 59 feet of masonry in the piers, as a base, and 203 feet in height of ironwork. The total length of the viaduct is 1,813 feet. Of this the iron portion is 1,470 feet in length; the remainder is of masonry. The ironwork consists of seven spans, including three on the Marvejols side, making a length of 887 feet; two on the Neussargues side, 341 feet long, and three supported by the central arch, together 242 feet.

The straight girders are of simple lattice work, consisting of St. Andrew's crosses, and are 17 feet high. The way is placed at a level of 5½ feet below the upper booms. The ironwork of the large piles next the arch is constructed in six stages, and is 200½ feet high, 49 feet by 23 feet at the base, tapering to the dimensions 16½ feet by 7 feet 8 inches at the top. The chord of the arch is 165 meters, or 541 feet, in length, with a rise of 60 meters, or 196¾ feet, and the depth at the crown is 10 meters, or 33 feet. It consists of two principal frames of latticework, 20½ feet apart at the middle of the arch, opening out to a width of 65½ feet at the ends, in order to give great stability to the arch for resisting high winds.

All the proportions have been calculated for a maximum stress, under the combined efforts of load and wind, of 6 kilogrammes per square millimeter, or 3.81 tons per square inch. The force of wind has been taken as 31 lbs. per square foot whilst the trains circulate, and as 55 lbs. per square foot without trains on the viaduct, when circulation would be impracticable. In comparing the influences respectively of the load and the wind on the co-efficients of stress, it is notable that, in general, the main portions of the arch are subjected to stress as follows:

2 kilogrammes		per square centimeter, or 1.27 ton per square inch, under the weight proper, or permanent load.
2	"	" under the surcharged loads.
2	"	" under the force of wind.

The maximum variation of stress by variation of temperature takes place at the crown of the arch, being 0.40 per ton per square inch, for 30° Centigrade, or 54° Fahrenheit.

For the lattice portions of the arch the stress is, under the weight proper, 1 kilogramme or 0.625 ton; for the surchage it is the same; and for the wind only, 3 kilogrammes, or 1.9 ton.

The total weight of the ironwork will be about 3,200 tons, and the cost, including that of the masonry, will amount to £124,000, being at the rate of £68 per lineal foot.—*Abstracts of Inst. Civil Engineers.*

ON THE PAST AND PRESENT WATER SUPPLIES OF CALCUTTA.—Mr. Pedler, in a valuable paper, contrasts the existing and past supplies to this town, and by a series of tables shows the importance to health and life, especially in the East, of a pure water supply. The former supply to Calcutta was from tanks and wells in the city, whose natural impurities were increased by the heat of the climate, which, especially at certain seasons, would tend to develop the incipient germs of animal life, whilst aiding the production of chemical compounds. The present supply is pumped from the Hooghly at Pultah; it is there collected in settling tanks, and after subsidence it is filtered through sand and then supplied to Calcutta; and on analysis, although the water is not of "great organic purity," it is well within the class of "fair organic purity," according to Dr. Frankland's standard, and compares well with English town supplies. The tables in this paper show the effect of impure water on the general mortality of the town, especially with regard to cholera, typhoid fever, and other diseases. Professor Wanklyn's system of analysis was adopted, instead of the refined one of Dr. Frankland, which was considered to take too much time, although more perfect.

The quality of the supply on the old system is described by the author thus: "A good average quality of Calcutta, or shallow well water, may be made by mixing six parts of our hydrant water with from one to two parts of the most concentrated Calcutta sewage." In 1879, 7,464,159 gallons of filtered water were supplied daily, to a population of 429,535; that is, 17.4 gallons per head. The total supply, filtered and unfiltered, was 8,556,025 gallons, or 20 gallons per head per day; it is, however, proposed to double the supply of filtered water to 16,000,000 gallons, or 37.2 gallons per head per day. (The average supply in large towns in England is 25 gallons per head).

The seasons have a very strong effect on the quality of the water, the rainy season greatly increasing its purity; the melting of the snow on the Himalayan range helps in this direction, and the river is most pure in October.

The total solid impurities in October are 11.30 parts in every 100,000 parts of water, and in May 21.68.

It is proposed to take the supply of water from the Hooghly rather nearer Calcutta, but the author seems to be rightly against this, on account of the danger of increasing the impurity by the tidal water.—*Abstracts of Inst. of Civil Engineers.*

JACQUEL'S TUG SYSTEM.—It has hitherto not been possible to use steamboats, whether paddle or screw, on canals of small section, for three reasons, viz., 1st. Because the waves generated by the propellers would destroy the sides of the canal; 2nd. The propellers themselves would be very liable to injury when passing through locks and other narrow places; and 3rd. Such boats cannot take a sufficiently large cargo in these canals to pay expenses.

In the steam tug system of Paul Jacquel of Natzweiler, Alsace, the screw is within the body of the ship, and surrounded by a cylinder or tunnel, and is fed with water by two large channels or passages leading from the sides of the boat to the front face of the screw. The advantages claimed for this arrangement are: 1st That the screw is protected from injury: and, 2nd. That the stream of water thrown astern so concentrated in direction by the cylindrical casing that the banks are preserved from injury. 3rd. The boat being a tug, not herself carrying a cargo, and consequently drawing always the same depth of water, can transport a large train of barges, at from three to four times the speed of horses. 4th. These tugs can always depend on their rudders for steering power, and thus render the use of steering poles unnecessary. These poles being invariably used with ordinary canal boats, and being constantly driven from 3 to 5 feet into the banks of the canals, render the maintenance of the latter very expensive, and frequently cause dangerous infiltrations.

The author accompanied Herr Jacquel on the trial trip of his first tug on the Saar coal canal, which was so successful that he is now engaged in organizing a complete sytem of steam transport on this canal.—*Abstracts of Inst. of Civil Engineers.*

THE BORING FOR THE PANAMA CANAL.—A brief account of the borings which have now been made for the Panama Canal has been communicated to the French Academy by M. de Lesseps; and they are of a nature to show that the work of excavation will be less arduous than was at first supposed. The preliminary surface bores, and the examination of boulders found along the route, had led the engineers to expect that the Culebra mountain, separating the maritime plains of the two oceans, was formed of a massive compact rock covered with a layer of vegetable humus only a few yards thick. But since the month of March last several deep bores have been made into the summit of this hill. Three of these begin at altitudes of about 100 feet above the level of the sea, and are already some 40 feet deep; but as yet no rocky strata have been encountered. The soil, in fact, is a conglomerate of clay mingled with globular fragments of dolomite varying in size from sand to pebbles. These curious balls of stone are paralleled by the resinous trachyte found in the islands of Ponza, between Terracina and Gaëta, in the Mediterranean. The balls are, strictly speaking, ellipsoidal, and crumble on exposure to the air, splitting up at the same time into concentric shells with a hard kernel inside. The boulders scattered along the track are of the same formation, and the many colored clays cut through are evidently due to the decomposed balls. In short, the rocks of this part of the isthmus appear to be all clayey breccias and conglomerates, which will give a stable slope to the great cuttings without seriously impeding its excavation.

THE MONT BLANC AND SIMPLON TUNNELS. According to the Paris correspondent of the *Gazzetta Piemontese*, the supporters of the rival tunnels are actively at work, but the prospects of the Mont Blanc scheme are the brighter. The Commission selected by the French Chamber of Deputies to consider the matter, has returned from inspecting the places concerned; and it is believed that their impressions were favorable to the Mont Blanc. According to the surveys of MM. Lepinay and Garola, the line can be carried from Bonneville to the northern entrance of the tunnel, and from Torea to the southern entrance, without exceeding a gradient of 12.50 in 1000, and that without serious difficulty. At the Simplon, on the other hand, new surveys are being made in hopes of reducing the gradients to 13 in 1000; but, in order to do so, it will be necessary to erect a viaduct 200 meters high over the Diveria, and to perform other lesser engineering works. In order to connect the tunnel with the Jura railways a branch line would have to be constructed, which would have three tunnels (one of them 8 kilos. long), and would cost 100 million francs. For the same sum, not only the lines of access to the Mont Blanc, but the whole tunnel as well, could be executed. The report of the Commission is being prepared by M. Sesguiller, and he promises that it shall be presented to the Chamber during the present session. If the decision is favorable to the Mont Blanc, negotiations will be immediately commenced with Italy, in order to agree on the division of the expense. It is said that the majority of the Commission are in favor of asking Italy to undertake the construction of the southern lines of access, while France bears all the expense of the tunnel itself. The correspondent learns that an English company designs to tender for both the Channel Tunnel and that of the Mont Blanc, with all its lines of access. An international company is talked of to construct and work the whole line from Dijon through to Broni.

CONTINUOUS BRAKES.—Earl de la Warr, in the House of Lords, recently, called attention to the subject of continuous brakes. His lordship dealt at some length with the unsatisfactory state of things revealed by the return for the half-year ending December, 1880, pointing out that upon the whole there were only about seven companies out of 90 in the United Kingdom who were actively carrying out the recommendations of the Board of Trade, and that the number of carriage stock so fitted with continuous brakes amounted only to 11 per cent. of the total carriage stock of the country. Under these circumstances did the Government propose to take any steps to enforce the regulations of the Board of Trade? Lord

Sudley, in replying, seemed desirous of covering the supineness of the railway companies by stating that 17,654 carriages, or 41 per cent. of the whole stock, were fitted with continuous brakes. A glance at the returns, however, shows this to be a complete mistake, for nearly half this number are not continuous but sectional brakes, chiefly in use on the London and North-Western and Lancanshire and Yorkshire railways. The remainder are certainly continuous, but not much more than one-half of them are automatic, and those which are, form, as Earl de le Warr correctly stated, only 11 per cent. of the whole carriage stock of the country. Again, we are informed that the Board of Trade have been in communication with the London and North-Western Railway Company, and it was hoped that by the pressure of public opinion and the efforts of the Board, the end which the noble lord had in view would be brought about without legislation. Lord Colville, in supporting the action of the Great Northern Railway Company, of which he is chairman, congratulated himself on the fact that his company had fitted so many vehicles with Smith's vacuum brake, and made the remarkable statement that the Midland Railway and the London and North Western Railways were also applying the Smith's vacuum brake to their stock. His lordship was, no doubt, unaware that this was not the fact. On one point, however, he had been better informed, for he went on to say that it was generally believed "that if you made the Smith's vacuum brake automatic, you spoiled it." Our opinion of automatic vacuum brakes is much the same as that of his lordship.

IRON AND STEEL NOTES.

IMPROVEMENTS IN THE BASIC BESSEMER PROCESS.—Steelmaking from phosphoriferous pig iron seems to made rapid strides on the Continent, for we hear that new Bessemer works are under construction at Ars on the Moselle, in Lorraine, and at Volklingen, near Saarbrucken, both of which are intended to make steel from the cheap "minette" iron ore, a description of ore resembling much the Cleveland oolitic ironstone, and which is found in enormous deposits in Luxemburg and Lorraine. When the basic process with a converter lining of dolomitic bricks was first introduced, the Rheinische Stahlwerke at Ruhrort, and the Horder Berg-und Huttenverein were not slow in appreciating its value, and to secure the patent rights for the German empire. Though the validity of the patents was energetically contested by a combination of German ironmasters, the patentees succeeded, nevertheless, to override all opposition in the various law courts where the matter was to be decided. The first step was the introduction of basic bricks for converter linings instead of the usual ganister or fire-brick lining, the second that of the addition of basic fluxes in combination with a prolonged afterblow, after the elimination of silicon, carbon, and manganese from the metallic bath. It was then considered essential that the basic cinder should contain from 36 to 40 per cent. of lime and magnesia, and only from 8 to 20 per cent of silica, and that the fluxes added to the metal should be, firstly, a mixture of about 9 parts lime and magnesia, with 1 part red oxide of iron; and secondly, after a blow of 6 to 10 minutes a mixture of 2-3 parts of lime with 1 part of oxide of iron, such as red hematite. The admixture of oxide of iron proved the more necessary the less the quantity of manganese was in the pig iron, and whenever the same was very large it could be left out altogether.

It is now well understood that the phosphide of iron only begins to be decomposed after all silicon and carbon is gone, that is after the characteristic carbon lines have completely disappeared in the spectroscope, and that its decomposition requires afterblowing of several minutes, when only the oxidized phosphorus will combine with the bases of the flux, chiefly with its lime and oxide of iron, which combination is accompanied by a voluminous emission of brown smoke, caused by burning iron. After the removal of the phosphoriferous cinder, spiegeleisen was then added, in order to reduce any oxide of iron which was dissolved in the fluid metal, and besides to dose it with sufficient carbon for becoming ingot iron, mild steel or hard steel, as required. This mode of procedure was the usual one with the grey phosphoriferous pig iron; the afterblow has, however, some inconveniences, which consist in the loss of metal and the greater amount of time. The Rheinische Stahlwerke have therefore tried to replace the afterblow by another oxidizing reaction, and to employ combined oxygen instead of free atmospheric oxygen for the elimination of phosphorus. The bearers of combined oxygen are the oxides of iron and manganese, which are introduced either in the solid or in the molten state, and intimately mixed with the metallic bath. The quantity of oxides is determined from that of phosphorus, and their oxygen ought to contain as much as 25 per cent. more than the free atmospheric oxygen, which would have to be blown in the metal, if it were to be finished by the usual afterblow.

The basic process has been in successful operation at Ruhrort since September 22, 1879, as well as at Horde. Licenses to use the patents, which were partly acquired from Mr. S. G. Thomas, partly taken out independently, have been granted in Germany and Luxemburg to the following iron and steel works, viz.: Gebruder Stumm of Neunkirchen, the Dillingen Iron Works near Saarbrucken, Gebruder Gienanth of Kaiserslautern, Messrs. Les Petits fils de Fois de Wendel & Co. of Hayange, Messrs. de Dietrich & Co. of Niederbronn, the Burbach Iron Company, the Rothe Erde Iron Works of Aachen, the Lothringen Iron Works of Ars-on-the-Moselle, the Maximilianshutte of Regensburg, and the Bochum Steel Works. It appears that, besides the Bessemer converter, the dephosphorising process makes favorable progress in the open-hearth furnaces as well, when basic flukes, such as lime, dolomite, oxides of iron and manganese are employed. Among their number reappears the fluoride of lime, fluor spar or "cand" of the

Cornish miners, which was patented some fifteen years ago by the late Professor Theodor Sheerer, of the Bergakademic of Freiberg, Saxony, for the purpose of dephosphorizing iron in the puddling furnace. When fluoride of lime was tried at the Horde Works, at the instance of Professor Sheerer, it was found that other combinations of lime, when in a fluid state, would react upon the phosphorus as well; for instance, chloride of lime and also chloride of magnesia, though they are more liable to be decomposed into chlorine and lime or magnesia by heat alone, while for the decomposition of fluoride of lime the presence of silica is essential. All these fluxes will, of course, act as well in the Bessemer converter; and as fluoride and chloride of lime form a very thin and fluid cinder, they seem to be far better suited for the washing out of phosphorus out of the metallic bath, than caustic lime or magnesia, or a mixture of both, which do not melt, and therefore come very much less in contact with the particles of phospbide of iron which are to be decomposed, than a more fluid substance.

RAILWAY NOTES.

The St. Gotthard Railway.—This railway is now so rapidly approaching completion that a table of the fares to be charged on it are already printed. Starting from Rotkreutzi 11 miles from Lucerne, the St. Gotthard line runs along the western shore of the Lake Zug, round the base of the Righi and by Lake Lowerz, striking the Lake of Lucerne at Brunnen. From Fluelen the line begins to ascend the valley of the Reuss, attaining an altitude of 1558 feet above the level of the sea at the village of Erstfeld, five miles from Fluelen. Up to this point the gradient of the line nowhere exceeds 10 in 1000; but from Erstfeld to the next station, Amsteg, it rises 26 feet in every 1000. From Amsteg the line runs through a number of short tunnels and over a number of bridges to Gurtnellen, eight miles from Fluelen, where it attains an altitude of 2427 feet. From Gurtnellen, the line ascends the mountain side in a series of bold spirals, crossing the Reuss several times, and passing through the Pfaffensprung tunnel, 1487 meters in length. And then, running through the Wattingen tunnel, reaches the station of Wasen, 3008 feet above the sea level. Leaving Wasen the line runs back again in the direction of Fluelen; then, turning, passes through the Naxberg tunnel, 1570 meters in length, and reaches the station of Goschenen. Here the St. Gotthard tunnel, nine and a-half miles long, begins.

Ventilation of the the Mont Cenis Tunnel.—A recent report by Signor Frescot, one of the engineers of the railways of Upper Italy, gives some interesting facts with regard to vetilation in the Mont Cenis Tunnel—facts which may be useful for the solution of the same problem in the St. Gotthard. The Mont Cenis Tunnel is 12,500 meters in length, and has a capacity or 500,000 cubic meters. The mean temperature is 25° C. In winter this causes sufficient natural ventilation, aided by the difference of altitude of the two extremities (132.5 meters). But in summer the external and internal temperatures are often equal, and artificial means of ventilation have to be adopted. It is a question, as will at once be seen, of considerable importance. The passage of twelve trains in the day may be assumed containing 2500 passengers, each passage through the tunnel occupying half an hour. The locomotives burn anthracite, which produces less carbonic oxide than coke, and the combustion is rendered as complete as possible. Now, it is estimated that the average total production of carbonic acid in the tunnel per day is 6987 cubic meters, of which 6930 cubic meters are attributed to the trains, the rest to employes, passengers, and lights. The normal proportion of carbonic acid in the atmosphere varies from 0.0003 to 0.0005. People can live in an atmosphere containing as much as 0.005. It has been proposed to attain in the Mont Cenis the same degree of purity as in our Metropolitan Railway, or 0 0015 of carbonic acid. With this view, a large centrifugal ventilator has been set up on the Bardoneche side; it is driven by water, which is abundant there. The entrance of the tunnel is closed by a door, which the trains open on passing under the arch, and close after passing. In winter, and also during some fresh nights in summer, the machine can be stopped, and any necessary repairs made. In addition to the ventilator, there is in use the compressing and aspirating apparatus that was employed in making the tunnel. Notwithstanding these means and care bestowed on the fires of the locomotives, there is reason to fear that the present ventilation would prove insufficient in case of even a small increase of the traffic.

ORDNANCE AND NAVAL.

Austrian Torpedo Boats.—The official trial of the first of two sea-going boats built for the Austrian Government by Messrs. Yarrow & Co., of Poplar, was carried out last month, when the speed realized was considerably in excess of that stipulated for in the contract. The boat is one of several now in course of construction for various governments, by Messrs. Yarrow; she is of the "Batoum" type, but is in many respects an improvement upon that vessel, which was built last year by the same firm for the Russian Government. The present vessel, which is steel built throughout, is 100 feet long by 12 feet 6 inches beam and 6 feet 6 inches deep, which gives a thorough seagoing craft, and one capable of stowing sufficient fuel for a run of from 800 to 1,000 miles at a ten-knot speed. She is fitted with a pair of compound overhead cylinder engines, the high-pressure cylinder being 12½ inches and the low-pressure 21¼ inches in diameter, with a 16-inch stroke. Her boiler is of the locomotive type, having 922 square feet of heating surface, and being placed forward with the engines aft. She is propelled by a single screw, 5 feet diameter and 6 feet 6 inches pitch. She

has a closed stokehole, with a fan drawing the air supply from the engine room, into which air is admitted by four small siphon inlets on deck in place of one large ventilator as formerly used, which is one of the improvements introduced by Messrs. Yarrow. Another and, in fact, the principal new feature, is, that the torpedo tubes—there being two for two Whitehead torpedoes—are completely encased within the bows instead of projecting from it, as formerly, and provision is made for a man to go down and obtain access to the front end of the tubes if necessary. The boat is fitted with bow and stern rudders, and is steered from a conning tower placed forward, steam steering gear being provided. This, coupled with the bow rudder, which is balanced, adds very considerably to the rapidity with which she can be manœuvred. The officers' quarters are placed aft and those of the crew forward. Another feature is the provision of means for working the engines at high pressure if the condensers get damaged in action. Should she spring a leak ample pumping power is provided, there being a 2-inch hand pump, a 3-inch steam pump and the 4-inch circulating pump of the engines available. The trial was made with twenty persons on board and 2½ tons of coal in her bunkers, which is sufficient to carry her over a 300 mile run. Her engines are of 550 horse-power indicated, and this was obtained on the trial with a pressure of 112 lbs. per square inch and 440 revolutions per minute. The speed attained was 22.1 knots, being 1.6 knot above the speed stipulated for in the contract, which is 20.5 knots. Altogether the results were highly successful, and the Austrian Government officials expressed their satisfaction with the performance of the boat.

A New Submarine Vessel.—A young Roumanian engineer, Trajan Theodoresco, has succeeded in constructing a submarine vessel which puts everything that has gone before in submarine navigation completely in the shade. This boat, up to a certain maximum size and corresponding tonnage, it is said, may be navigated under water for twelve hours at a stretch, at a depth of 100 feet; she may, however, according to the inventor, be lowered to over 300 feet below the surface of the water, and without coming into contact with the atmosphere. On the surface of the water the vessel may be manœuvred under the same conditions as an ordinary steamboat. Her speed, however, is not so great as that of steamers, but greater than that of sailing vessels. The submersion is effected by screws and vertically, either suddenly or successively, and the vessel is raised in the same way. If once under water, sufficient light is supplied enabling those on board to see all obstacles at all distances up to 130 feet, and the movements of the boat may be so regulated as to avoid them. The air supplied for the crew is said to last for from twelve to fourteen hours. In case of need, the reservoir containing the air may be refilled, while under water, for another twelve hours, pipes telescoping into each other being directed to the surface for that purpose. The propulsion of the vessel and its submersion are stated to cause no noise. Should all these particulars prove correct, the novel boat will be the most formidable vessel for torpedo warfare. But she may also be turned to more useful purposes. In the Matchin Canal, near Braila, there lies, since May, 1877, the "Lutfi Djelit," which had on board the war-chest of the Turkish Danube flotilla, amounting, so report says, to several million piasters. It might be possible to recover that sum by means of the new submarine boat, and if the experiment should prove successful, it would at the same time be profitable.

New Gun Vessels for China.—An important addition has just been made to the fleet of gun vessels with which the Chinese navy has been supplied by Sir W. G. Armstrong & Co. during the last few years. Already eleven vessels have been sent out from time to time, differing in details, but uniting the peculiarity of extraordinary gun power in diminutive craft. The two new vessels differ essentially from the preceding eleven in combining great speed with great gun power. They resemble the others, however, in being wholly unarmored. Their displacement is 1350 tons. They are built of steel, and are propelled by twin screws driven by compound engines of, together, 2600 indicated horse-power. They each carry two 26-ton 10-inch breech-loading guns mounted upon center pivots, one forward and one aft. Each of these heavy guns commands a nearly all-round fire. The charge of the gun is 180 lbs. of powder, and the weight of projectile 400 lbs., the penetrative powder equal to piercing 18 inches of solid, unbacked iron plate. They carry, besides, in each, four 40-pounder breech-loading guns, two 9-pounder breech-loading guns, two Nordenfelts, and four Gatlings, and, furthermore, two steam cutters fitted with spar torpedoes. The engines, boilers, magazines, and machinery are entirely below the water line, and are further protected by a steel-plate under-water deck, the space between which and the main deck is divided into numerous watertight compartments, in which coal is stored, thus adding to the protection afforded by the deck. Hydraulic steering gear is provided and placed below the water line, with alternative hand gear and tiller. The vessels are also armed with a formidable steel knife-edged spur, or ram. The coal bunkers take 300 tons of coal, and with that quantity the vessels can run continuously at a speed of about eight knots for weeks together. On the 14th and 15th inst. the new vessels went through a complete course of trials off the mouth of the Tyne, under Admiralty inspection. Their speed was tested over a course of 10¾ knots, and was shown to be, with all weights on board, on the average of two runs each, over 16 knots in one vessel and 16 knots in the other. The guns were fired with battering charges abeam, ahead, and astern, and at different elevation up to the maximum. Not the slightest sign of weakness was exhibited in any part of their structure. The handiness or power of manœuvring was found remarkable. With engines stopped suddenly, they were

brought up in about 3½ lengths. Reversing the engines brought them up in about 1½ lengths. With one engine driving ahead and other astern, they circled rapidly to port or to starboard in their own length. With the hydraulic gear, the rudder was put over from hard-a-port to hard-a-starboard in eight seconds. The vessels were kept easily circling round a drifting target at about 150 yards, while the target was being riddled by the machine guns. Without claiming too much for these vessels, it should be remarked of them that the penetrative power and range of their guns measured by the accepted official standard, exceed those of any gun yet afloat, except those of the English "Inflexible," and the Italian "Duilio. No unarmored ship that carries guns can be compared for a moment with them, and no armored ship equals them in speed The nearest is the "Duilio," of nine times their size. Thus their vastly superior gun power would make them most formidable to the largest unarmored vessels, and their superior speed and greater range and power of artillery would enable them to in some measure cope with an ironclad, since they could ordinarily choose their own distance, and from their diminutiveness would be very hard to hit; nor would a single shot by any means disable them, owing to the under-water and other protection given to their vital parts. As skirmishers to open attack, or as cavalry to harass a retreat, they would prove valuable adjuncts to a first class navy, and they are not subject to the rapid depreciation which the progress of artillery imposes upon a costly and necessarily limited ironclad fleet. The vessels are being commissioned by Admiral Ting with officers and crews sent from China, and Admiral Ting will shortly call in at Portsmouth for the purpose of paying his respects and showing his vessels.

BOOK NOTICES.

Publications Received.

Through the kindness of Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers of the Institution.

The Flow of the River Thames. By John Taylor, M.I.C.E.

The Protective Works for Preventing the Threatened Outbreak of the South Rangitata River, N. Z. By John Henry Lowe, M.I.C.E.

Portland Cement Compo and Concrete at Garvel Dock Works, Greenock. By Walter Robert Kinipple, M.I.C.E.

Dredging on the Lower Danube. By Charles Henry Leopold Kühl, M.I.C.E.

Explosions of Fire Damp. By Prof. Haton de la Goupilliere.

The Use of Cellular Caissons. By Charles Andrews, M.I C.E.

The Empress Bridge over the Sutlej. By James Richard Bell, M.I.C.E.

The Paroy Reservoir. By William Bell Dawson, A.M.I.C.E.

Scarborough Harbor Improvement. By John Hawkins, M.I C.E.

Friction of Timber Piles in Clay. By Arthur Cameron Hurtzig, A.M.I.C.E.

The Osakayama Tunnel. By Thomas Munson Rymer-Jones, M.I.C.E.

Annual Report of the Astronomer in Charge of the Horological and Thermometric Bureaus of the Winchester Observatory of Yale College. New Haven: Tuttle, Morehouse & Taylor.

Monthly Weather Review for July. Washington: Government Printing Office.

A Manual for Managers, Designers and Weavers of Textile Fabrics. By Alfred Spitzli. West Troy: A. & A. F. Spitzli.

This is in the fullest sense a technical work, but it is designed to be of great value to all interested in the manufacture of textile fabrics. Arranged on the plan of a dictionary of technical terms, it is occasionally expanded to include the explanation of a process, or the description of a machine and its working.

It includes also, rules, tables and elementary instruction for beginners.

A Manual of Sugar Analysis. By J. H. Tucker, Ph. D. New York: D. Van Nostrand. Price $3.50.

The question of sugar adulteration has quickened the interest in all methods of detecting fraud. There has been of late a brisk demand for good guides to analysis of sugars.

The book before us seems to fill the requirements of the Chemist, who wants a complete manual for this branch of analytical work.

The scope of the treatise, which fills a royal octavo of 350 pages, may be inferred from the list of topics treated by chapters.

Chap. I. The Chemistry of Sugars as a class.
II. Cane Sugar, or Saccharose.
III. Dextrose and Levulose and Invert Sugar.
IV. Lactose or Milk Sugar.
V. Determination of Specific Gravity.
VI. Determination of Cane Sugar, Optical Method.
VII. Determination of Cane Sugar: Chemical Method.
VIII. Determination of Dextrose and Invert Sugar.
IX. Analysis of Raw Sugar.
X. " Molasses and Syrups.
XI. " Cane and Cane Juice.
XII. " the Beet and Beet Juice.
XIII. " Waste Products.
XIV. " Starch Sugar.
XV. Estimation of Milk Sugar.
XVI. Estimation of Dextrose in Urine.
XVII. Chemistry of Animal Charcoal.
XVIII. Analysis of Animal Charcoal.
Appendix.

A Handbook of Electrical Testing. By H. R. Kempe, M.S.T.E., &c. New Edition. Revised and enlarged. E. & F. N. Spon. 1881.

It is impossible to give a correct idea of the value of this work. There is none other with which it can be compared. Rivals it has no any. True we have books that treat of testin .

GENERAL LIBRARY University of MICHIGAN

We have indeed small works, such as that of Hoskier, devoted entirely to testing, but in most cases testing is discussed in one or two chapters in books which deal with electrical matters generally. Mr. Kempe, however, has made testing *the* subject of his book, and any other subject that is discussed is discussed solely because of its connection with the principal subject. Now, a fair knowledge of testing is as necessary to the electrical engineer as a knowledge of certain branches of applied mathematics is to the engineer who undertakes the designing of bridges or similar constructions. Testing is a system of measurement, and implies a knowledge of the tools used as well as a knowledge of the properties of the materials employed. The tools used by electricians in their measurements are instruments of great delicacy and precision, and have a scientific as well as a practical value. The work before us describes these instruments, clearly showing the principle upon which the instruments is based, and the best methods of using it. It is with a certain amount of hesitation that we venture to hint at a seeming deficiency. The recent astonishing development of electric light apparatus opens a new field for testing operations, and we should have liked to have seen a chapter devoted to this special branch of the subject. Of course, it may be answered that the expert in testing can without the slightest difficulty apply his knowledge, inasmuch as no new principles are involved, and only care to be taken that his instruments are suited to large currents.

This work deals with testing from the standpoint of a telegraphist and has in view a thorough description of the tests requisite during the manufacture, laying, and repairing of as submarine cable. The value of the work arises not only from its comprehensiveness, but more from the excellent method pursued by the author. He not only supplies tests as devised for special purposes, and duly gives credit to the originator, but he discusses fully and freely the best conditions for making the test. The author is fully imbued with the idea that no effort should be spared to make the reader understand the "Why and the wherefore," and therefore he almost always illustrates his description by a numerical example. Thus to enable our readers to judge more easily our meaning, we indicate the method pursued in the discussion of Poggendorf's method of obtaining the E. M. F. of batteries. The method is in the first place described with the aid of a diagram, then a numerical example of the method is given, followed by remarks on the best conditions for making the test, and concluding the special subject by considering the possible degree of accuracy attainable. The method adopted by an author may be admirable, while his matter may be involved and difficult to understand. In this case the matter and method are equal, the former being clear, concise, and to the point.

MISCELLANEOUS.

STANDARD DANIELL CELLS.—At a recent meeting of the Physical Society Dr. James Moser exhibited a novel form of Daniell cell of the gravity type, intended as a standard of electromotive force. It consisted of a long glass vessel of tubular form, having a copper plate at the bottom immersed in sulphate of copper, and a zinc plate at the top immersed in sulphate of zinc. The two solutions are of course separated by their densities, but, as is well known, the copper solution tends to diffuse upwards into the zinc solution and deposit pure copper on the zinc plate. This diffusion is accelerated, too, by impurities falling from the oxidized zinc plate stirring up the solution below. Dr. Moser, however, prevents the sulphate of copper rising above a well-marked line of demarcation by simply suspending a small plate of scrap zinc by a string vertically into the liquid, so that the upward diffusion of the copper sulphate is arrested at the bottom of the suspended plate and copper is deposited on the latter. This cell is, however, not intended for yielding a constant current, and Professor Macleod, of the Indian Engineering College, Cooper's Hill, described a gravity Daniell devised by him for driving an electric clock. In this cell the two solutions are kept apart by surrounding the zinc plate with a cage of copper wire connected to the copper plate in the bottom of the cell. The trespassing copper solution is arrested by the cage, and copper is deposited on the wires, especially those on the upper sides of the cage immediately encircling the zinc. Dr. O. J. Lodge pointed out that this arrangement would not yield a correct standard of electromotive force, because all the copper plate was not wholly immersed in its own solution; it being a condition of accuracy that the zinc plate should be entirely immersed in the sulphate of zinc, while the copper plate is wholly covered by the sulphate of copper. Dr. Lodge is himself the inventor of a standard Daniell, which, we believe, gives very good results. In this, the copper plate and solution are contained in a glass test tube dipped into the sulphate of zinc solution; and the zinc plate is contained in a glass tube open at both ends and likewise immersed in the sulphate of zinc solution. In order to reach the zinc plate, the sulphate of copper has to diffuse out of the test tube, pass down the cell to the bottom, then rise up through the solution in the open tube. This is a process requiring considerable time, and it may be further checked by laying a piece of scrap zinc on the bottom of the cell.

A CORRESPONDENT of the *Times* writing from Shanghai in April last says "that the necessity for the preparation for a defensive war recently, woke China up very considerably. The telegraphs and the railways, and other modern productions of barbarian ingenuity, China has been forced to admit, are things that must be had even in a far eastern country, which has Russia for its most powerful enemy. Thus, it has come about that there is now more hope than ever that railway work and telegraph work will soon be common in China, and already a good deal of telegraph work is being carried out. A proposal to connect the capital with the Tientsin and the

Yangtsze by rail has been laid before the Throne by a most trusted general, and having been referred to the Governors-General of Chihli and at Nankin, it has been indorsed with their warm approval. But I hardly think the finances of China will permit her to embark on a scheme so extensive as this. All the money she can now scrape together from her impoverished exchequers or borrow from local banks will be required for the payment of the Russian indemnity. However, a railway from Pekin to Tientsin would not be so very costly, and it is now quite probable that the Chinese will be allowed by their paternal Government to set about making it at once. With the fear of invasion the desire for railways may pass away or grow weaker, but the events of the past few months have demonstrated to Chinamen the powerlessness of a country to avail itself of its resources for defence in an emergency, and the pride of the heads of the Government has been sufficiently wounded by proved incompetence, so that they will now exert themselves as strongly for improved inland communication as they formerly did against it.

THE DYNAMO MACHINE AND ROLLING STOCK. The electric locomotive of Dr. Siemens will doubtless be useful in many ways, and prove a good auxiliary to the steam locomotive, but it will be very long, if ever, before it supersedes the latter for general traffic. There is, however, some value in the suggestion of Lieutenant Cardew to use the dynamo-electric machine in conjunction with the steam locomotive in order to communicate the power of the latter to the wheels of the carriages in a train, without having to resort to the wasteful "grip" or friction of the driving wheels upon the rails. Moreover, it could be made to apply the brakes to the carriage wheels in stopping the trains. Lieutenant Cardew's plan is to have a dynamo machine on the locomotive and each carriage, the revolving armatures being mounted on the axles of the wheels, and all connected up together in such a manner that the current generated in the armature of the locomotive machine by the revolution of its driving wheel would circulate through the magnets of all the other machines, turning round their armatures, and consequently also the carriage wheels. When it was desired to stop the train, the engine driver and guard, by means of two switches under their respective control, would change the direction of the current and reverse the motion of the armatures on the axles of the wheels, thus tending to bring the latter to a stop. The check would be strongest at first, and gradually die away; but this is in accordance with Captain Galton's finding that a brake should apply a powerful force to begin with for a short time, followed by a gradually diminishing one, in order to prevent the skidding of the wheels, which takes place if a strong pressure is kept upon them while they slacken. At first sight it might seem against Lieutenant Cardew's plan that the wire connections to be made would prove very inconvenient in practice where trains are made up of different carriages; but this drawback could be overcome by properly designated contact pieces. With regard to the efficiency of the dynamo-electric machine for transmitting power, M. Mascart has shown it to be a half when it is giving out work most *rapidly*, and Professor Ayrton has proved it to be as much as three-fourths when giving out work most *economically*.

ELECTRIC LIGHTING IN COAL MINES.—The Royal Commissioners upon Accidents in Mines recently witnessed some very interesting experiments on the application of electric lighting to coal mines. The colliery selected for these experiments was the Pleasley Colliery, near Mansfield. The pits are about 1600 feet deep, and the workings are very extensive, but in the present instance the light was applied to three workings only, situated at a distance of about one third of a mile from the bottom of the pits. As it is a necessity in such an application of the electric light that the light itself should be absolutely cut off from all communication with the air surrounding the lamp, and also in order to permit of the use of a large number of separate lamps upon one circuit, the Swan system was employed. As our readers are aware, in this system the light proceeds from the incandescence of a fine fiber of carbon, the combustion of which is prevented by its being enclosed in an exhausted glass bulb. The light of such lamp varies from twelve to fifty candles, and as many as seventy lamps can be worked upon one circuit with an ordinary dynamo electric machine. The main wires were taken down the upcast shaft and connected at the bottom of the pit with cables, which were carried through the air passages till they arrived at the main levels. They were then taken along these main levels, and from them branch cables were carried up gates or side passages to the face of the actual workings. Here they were continued by insulated wires upon which the lamps were placed, and which were of sufficient length to reach to the extreme limits of the face of the coal that was being worked. The lamps themselves were enclosed in lanterns of a very ingenious construction, designed and made by Messrs. R. E. Crompton & Co., which enabled the very fragile glass bulbs to be carried about without fear of accident, and at the same time rendered it impossible that the fracture of the lamp within could cause an explosion, inasmuch as the air inside the lantern would suffice for the instantaneous combustion of the carbon filaments before the flame could be communicated to the external air. As in working the coal the men undercut the surface to the depth of 5 or 6 feet, and the superincumbent mass is then brought down by wedges or blasting. The new lamp was found to be admirably suited for the requirements of the workers, since it not only gave a light many times as intense as the lights it replaced, but it was equally brilliant in whatever position it was placed, and it required absolutely no attention. In addition to the lamps which were used in the actual workings of the pit, the pit bottom was lighted up with similar lamps. The number of lights employed in all was ninety-four, which were worked by the

current of an ordinary Gramme machine, driven by a portable engine, placed near the top of the upcast shaft. Had it been necessary, the number of lamps might have been considerably larger, but it was not desired to increase the scale of the experiment, as it was sufficient to test the practicability of the scheme. The whole of the arrangements were carried out under the personal superintendence of Mr. Harold Thompson, of the firm of R. E. Crompton & Co. The Commissioners, including Mr Warrington Smyth, Professor Tyndall, Professor Abel, and others, spent two days in examining and testing in various ways the success of the experiment, and are reported to have expressed themselves as highly satisfied with the results obtained. It seems probable that this attempt will lead to further and more extensive experiments of a simlar kind.

THE FAURE BATTERY.—We believe that quite a number of installations for lighting purposes have already been made in private houses, so that the full practical value of the apparatus will not long remain an unknown quantity. Meanwhile arrangements on a large scale are being made in London for the practical and commercial development of the invention. We have already taken pains to criticize the unwise and exaggerated claims made for the Faure battery in Paris with which the financial combination that had acquired the patents thought fit to take the public by storm, and pointed out that an interesting and valuable invention was likely to suffer from such a treatment. We are therefore the more gratified to learn that, in this country at all events, the value of the Faure battery is not likely to be damaged in the same manner, the names of those gentlemen (especially that of Sir William Thomson) interested in the matter being a sufficient guarantee that no more will be claimed for the battery than it can fulfill. So far as light-producing is concerned, Sir William Thomson probably suggested the real field for its usefulness, and an enormous field it should be, when he said that the battery would do for the electric light what a water cistern does for an inconstant house supply. It will also afford the means of obviating those interruptions in an electric light arising from irregularities in the motor, or from its temporary disablement, since if the dynamo-electric machine be employed to charge the batteries, and the latter are used to supply the light, the resulting current will be absolutely uniform. For working tramways and for some other purposes the batteries have been experimented upon with reasonable success, and doubtless much will be done with them in this direction. All this, however, is widely different from the original and sensational proposition to deliver batteries daily from house to house for giving light and power at prices competing with gas and steam; widely different, and infinitely more satisfactory, and within its legitimate limits, we may expect to see the Faure battery take a prominent place amongst the practically useful inventions of the day. Before dismissing the subject for the moment, we wish to correct two errors which have unfortunately appeared in a recent note. The first referred to the date of the Faure patent, and stated that inasmuch as the date of this patent was the 26th of May, and that detailed descriptions of the arrangement had appeared in the public journals before that date, the validity of the patent may be called in question. So far from this being the case, the date of the patent protecting the Faure battery is dated January 11, 1881, long before any descriptions were made public, and subsequently patents have been granted in most other countries, including Germany and the United States, where objections are most easily raised and successfully contested. The patent dated May 26, to which reference was made, is, we believe, for further modifications not yet made public. The second error referred to the mode of charging the Faure battery. It was stated that it could only be charged by a voltaic battery. Were this the case the arrangement would of course be utterly without commercial value. As a matter of fact it can be charged by any direct current generator — *Engineering.*

FORTH BRIDGE RAILWAY.—The Forth Bridge Railway scheme, which provides for a bridge over the Firth of Forth, together with approaches on each side, is likely to be proceeded with, it having been arranged by the various companies concerned—namely, the North British, Midland, North Eastern, and Great Northern—to modify the arrangements embodied in the former bill, so that the Forth Bridge Company may be able to complete the undertaking; and it is expected that improvements will be made in the route to the North, in addition to those which will be secured by the construction of the bridge itself.

THE SPEED OF THOUGHT.—Helmholtz showed that a wave of thought would require about a minute to traverse a mile of nerve, and Hirsch found that a touch on the face was recognised by the brain, and responded to by a manual signal, in the seventh of a second. He also found that the speed of sense differed for different organs, the sense of hearing being responded to in a sixth of a second; while that of sight required only one-fifth of a second to be felt and signaled. In all these cases the distance traversed was about the same, so the inference is that images travel more slowly than sounds or touch. It still remained, however, to show the portion of this interval taken up by the action of the brain. Professor Donders, by very delicate apparatus, has demonstrated this to be about seventy-five-thousandths of a second. Of the whole interval forty thousandths are occupied in the simple act of recognition, and thirty five thousandths for the act of willing a response. When two irritants were caused to operate on the same sense, one twenty-fifth of a second was required for the person to recognize which was the first; but a slightly longer interval was required to determine the priority in the case of the other senses. These results were obtained from a middle-aged man, but in youths the mental operations are somewhat quicker than in the adult. The average of many experiments proved that a simple thought occupies one-fortieth of a second.

AUTHORITIES differ on the physical properties of ammonia, but so far as liquid ammonia is concerned, it is, says *Science*, stated that at atmospheric pressure, and a temperature of 62 deg. Fah., 1 lb. of the gas occupies about 23 cubic feet, while 1 lb. of liquid ammonia would occupy only 36 cubic inches.

THE INDUCTION BALANCE IN SURGERY.—M. Trouvé has invented a very ingenious electric probe which when inserted into a wound indicates the presence of a foreign body, especially if it be a bullet, by closing an electric circuit and ringing an alarm bell. This instrument is, however, inapplicable in cases where it would be dangerous to probe, or where the perforation has partially healed up. Such a case is evidently that of General Garfield, the American President, and there appears to be some difficulty in telling the true locality of the missile. Professor Graham Bell, with that ardent desire to benefit the sufferer, which is characteristic of the whole nation, has suggested that the induction balance of Professor Hughes might be successful in indicating the true position of the ball, and in response to a telegram to that effect, Professor Hughes has promptly devised a modified form of the apparatus specially adapted for the purpose. Our readers will remember that this instrument is extremely sensitive to the neighborhood of small pieces of metal, although nothing tangible connects them, and it is hoped that by applying it to the surface of the patient's body the spot and probable depth of the ball will be ascertained. Should these hopes be realized a valuable instrument of research will have been added to the cabinet of the surgeon.

ELECTRIC LIGHTING ON THE CUNARD STEAMER "SERVIA."—The chairman of the Cunard Company is giving practical evidence of his faith in electric lighting by fitting the Cunard steamship Servia with 98 lamps. The contract is being executed by Swan's Electric Light Company. The 98 incandescent lamps are to be disposed in the following manner: Engine room, 20; propeller shaft tunnels, 10; grand saloon, 50, music room, 8; ladies' boudoir,6; smoking room, 4. The requisite current will be obtained from a No. 7 "Brush" dynamo-electric machine, the driving of which will be done by a special engine made by Messrs. John Fowler and Co., Leeds.

AN ABSOLUTE SINE ELECTROMETER.—The absolute electrometer of Sir William Thomson is a very elaborate instrument for measuring the electromotive force or mechanical attraction between the two poles of a battery in absolute units; but it is troublesome to use, and it can only give the result for a comparatively large battery. Professor Minchin has just constructed an absolute sine electrometer which combines convenience of manipulation and sensitiveness of action. It will in fact measure the electromotive force of a single cell. The apparatus chiefly consists of two parallel metal plates hung from a frame in such a way that they can be tilted through an angle from the vertical. One of the plates has an aperture cut in its middle, and this hole is very nearly closed by a movable trap or shutter suspended by two fine platinum wires from the upper edge of the perforated plate. The trap rests against finely pointed stops, and is brought flush with the inner surface of the plate. The opposite poles of the battery to be measured are connected to these opposite plates, which are then tilted from the vertical until an angle is found at which the attraction of the entire plate on the movable trap is exactly balanced by the weight of the trap. When this is so the electromotive force is proportional to the sine of the angle of displacement. This angle, the area of the trap, and the distance between the two plates, are the required quantities, and the electromotive force is calculated from them by a well-known formula.

THE SUN ELECTRIC LAMP.—*La lampe soleil*, as it is termed, is a new French electric lamp of considerable promise and some novelty. The light is formed by boring two converging holes into a small block or brick of marble, and inserting into these two carbon rods. The rods are separated at their points by a partition of the marble, and they nearly penetrate through the block. Their upper ends are connected to the dynamo-electric machine, and the current in traversing the wall of marble between their points makes it white hot. The carbons are slowly consumed, the gas escaping by the bore-holes, which are wider than the rods, and they are fed to the arc by their own gravity. The light is emitted by the bottom of the brick, which becomes calcined, and is of a mellow lustre like the sunshine. The cost is said to be only a sou per hour, the carbons consuming at the rate of a centimeter in that time. Already *la lampe soleil* has been introduced into several places in Paris, including the mayor's residence, and it will form a feature of the forthcoming exhibition. It is the invention of MM. Clerac and Bureau; but it reminds us of the electro calcic lamp patented by Mr. Wentworth L. Scott in 1878, wherein a block of lime or other earth is interposed between the electrodes of the arc. Mr. Scott did not arrange his apparatus like the sun lamp; but his intention was, we understand, to heat a piece of lime white hot by the current, just as it is heated by the mingling gases in the Drummond lime light.

AN IODINE CELL.—At a recent meeting of the Royal Society of Ediburgh, Professor P. G. Tait described a new form of constant battery devised by Mr. A. P. Laurie. Its leading merit is that it combines the simplicity of a single fluid cell with an electromotive as constant as that of the best double fluid cells. The liquid is a solution of iodine in iodide of zinc; the function of the dissolved iodine being to prevent polarization and consequent weakening of the electromotive force. The negative plate is of carbon and the positive of unamalgamated zinc. When the cell is not at work the zinc should be removed from the iodine to prevent local action. As tested by Thomson's quadrant electrometer, the electromotive force of this combination is very approximately one volt; and such is its constancy that after half an hour's short-circuiting the electromotive force was hardly at all diminished.